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USSR Report

SPACE

No. 15



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MANNED MISSION HIGHLIGHTS

EVOLUTION OF 'SALYUT' ORBITAL STATIONS

Moscow ZEMLYA I VSELENNAYA in Russian No 5, Sep-Oct 81 pp 10-17

[Article by K.P. Feoktistov, doctor of technical sciences, and M.M. Markov, candidate of technical sciences]

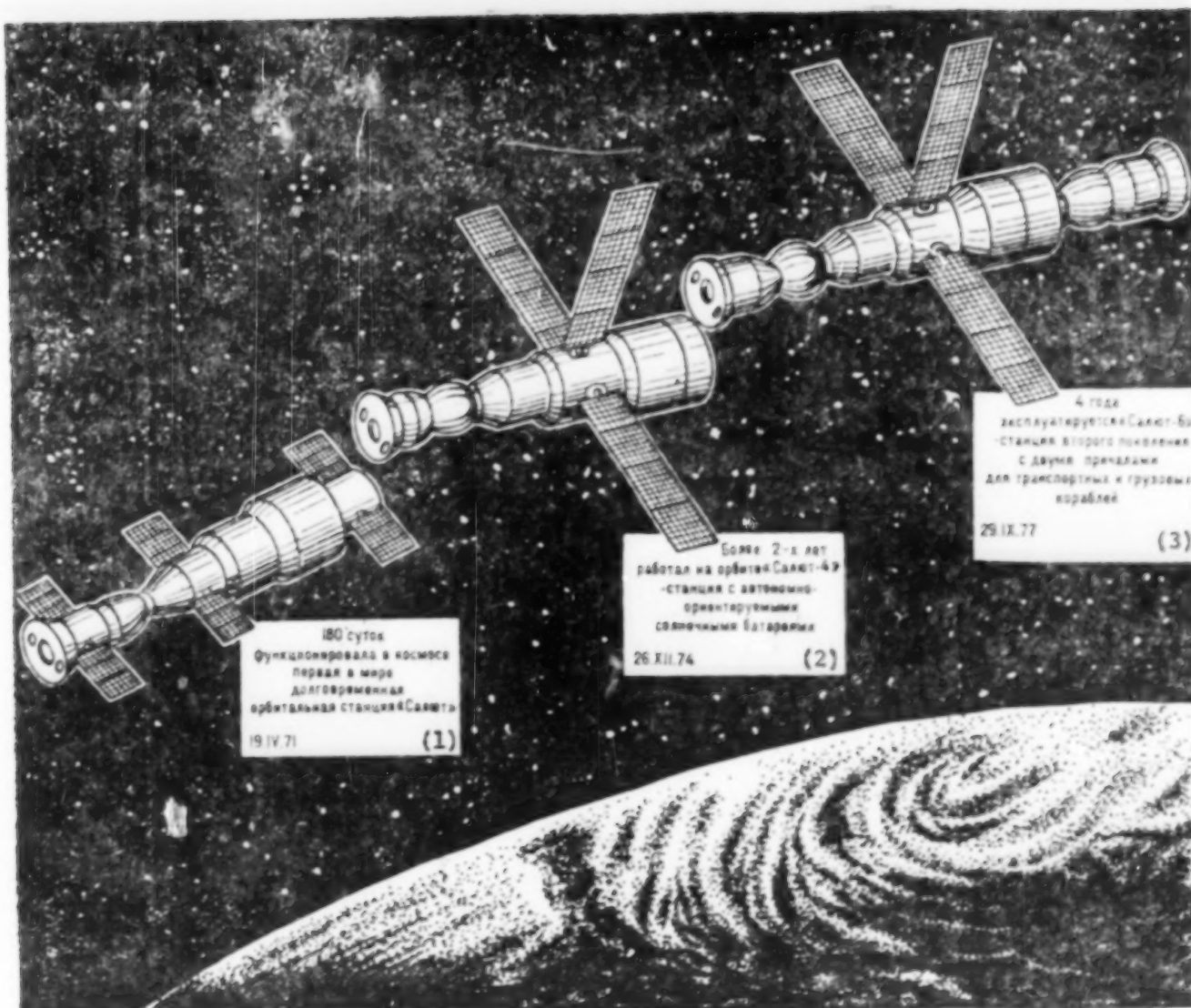
[Text] The first "Salyut" station functioned in orbit for about 6 months. The "Salyut-6" has already been in operation for more than 4 years. The crew of the "Salyut" flew for a total of 23 days, while L.I. Popov and V.V. Ryumin flew in the "Salyut-6" for more than half a year. In order for them to do this, it was necessary to create new systems and units and improve the characteristics of the station and the facilities for supporting a prolonged stay in space by man. The amount of research conducted and number of experiments performed was increased significantly.

The First Family of Orbital Stations

Direct work on the "Salyut" orbital stations began in 1969. Investigations that had been carried out by then showed that it was necessary to build an orbital complex consisting of a station and transport ships that would periodically deliver crews and various equipment. The station--the basic unit--had to have a power plant and complicated and expensive on-board systems and scientific equipment, so the expense of building it was higher than that for the construction of a transport ship. Consequently, the use of the station for the maximum possible time was economically justified. These considerations were used as the basis for the project.

In order to shorten the construction period and reduce the cost of the first station, it was decided to use as many units and separate systems from the "Soyuz" spacecraft, "Zond" automatic stations and other already developed projects as possible. However, most of the systems did not provide the necessary service life and were substantially reworked, while such basic systems as the heat supply, on-board complex control and actuating element control systems were essentially created anew.

Many problems were also encountered in setting up the station. In all manned spacecraft intended for short flights, only the equipment needed by the crew for domestic needs and the fulfillment of their service obligations was installed in the crew compartments. Basically, the instruments were placed in the instrument and service modules. This was necessary in order to save the weight of the equipment returned to Earth and, consequently, the weight of the parachute system.

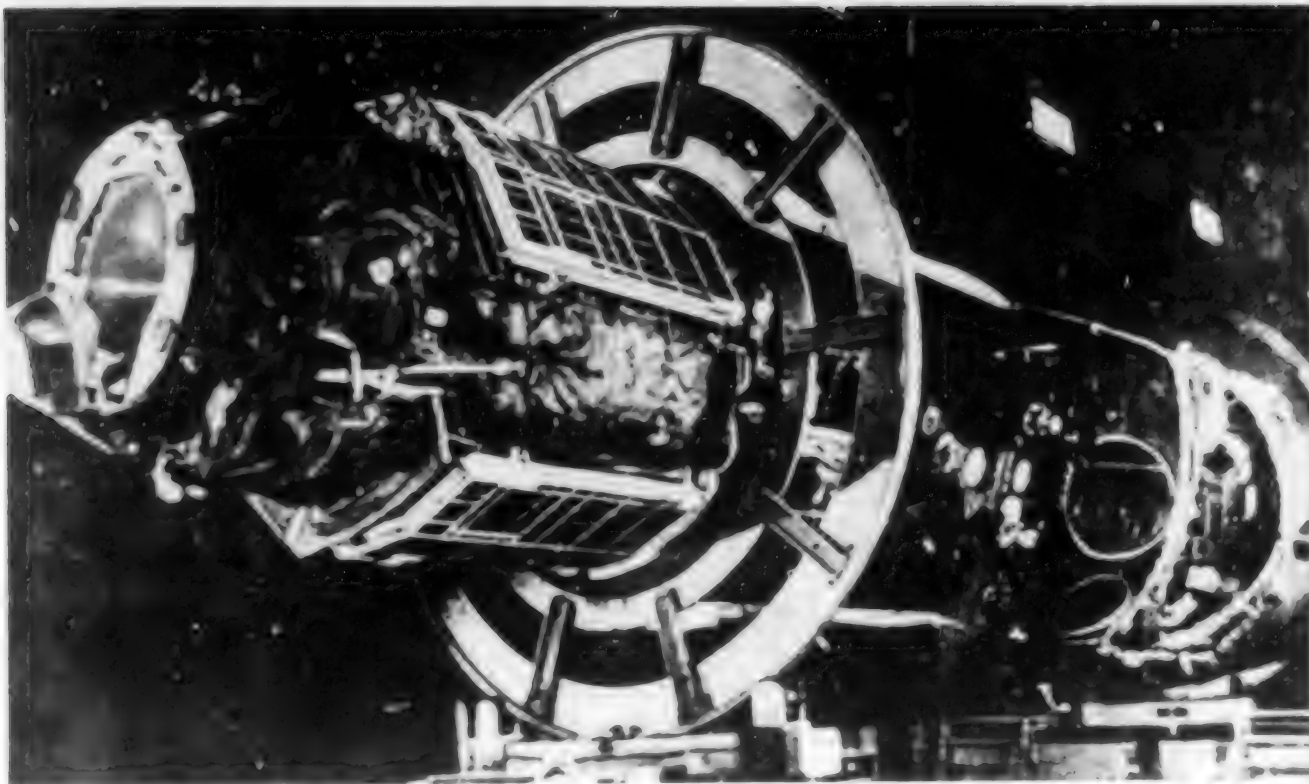


Orbital stations of different generations.

Key:

1. The first long-term "Salyut" orbital station functioned in space for 180 days (date of launch: 19 April 1971).
2. The "Salyut-4" station, with independently oriented solar batteries, operated in orbit for more than 2 years (date of launch: 26 December 1974)
3. The "Salyut-6," a second-generation station with two docking units for transport and cargo ships, has been operating for 4 years (date of launch: 29 September 1977)

The development of a station that was to function for an extended period of time with men on board required a different approach. The station's design had to provide the crew not only the conditions for the performance of their various research projects, but also had to enable them to intervene actively in the operation of the on-board systems, perform maintenance on them, and eliminate malfunctions. The question can be raised: but how did such automatic craft as "Molniya," "Voyager" and others manage to fly for several years? In principle, the station could also be built in an analogous manner, but the following facts must be taken into



The first "Salyut" orbital station in the final stages of preparation for flight.

consideration. In the "Salyut" there are many more units and mechanisms than in other spacecraft. In connection with this there is an increase in the probability of appearance of malfunctions. Repeated duplication of all elements would lead to an increase in weight. The presence of a crew on board made it possible to increase reliability by a simpler method: restoring the capacity for functioning of the most important elements during the operating process. Therefore, both the crew and a large part of the equipment were placed in a single sealed compartment--the station's working module. This was a compromise that provided suitable working and living conditions for the crew and the optimum location of more than 1,000 units with a total weight of about 4 tons.

The transfer compartment became the docking place for the transport ships. The provision equipment was placed in an unsealed service compartment, while the scientific equipment was located in a special module. The crew's working and resting area had a volume of approximately 60 m³, in which there were also control stations and places for eating, sleeping, hygiene and physical exercise.

The first "Salyut" station began its test flight on 19 April 1971. For more than 3 weeks (from 6 to 30 June 1971) G.T. Dobrovolskiy, V.N. Volynov and V.I. Patsayev

worked in the station. While returning to Earth, however, the crew perished as the result of depressurization of the descent unit. It was necessary to halt testing of the station in the manned mode. In this complicated situation it was important not only to increase the crew's safety, but also to overcome some psychological barrier in order to continue manned flights into space with confidence. Separate elements of the design were reworked on a "Soyuz" ship and the station itself and pressure suits that were to be used during injection into orbit and the descent to Earth were provided for the crew.

The flight of the "Salyut" showed that in order to increase the efficiency of future stations, it was necessary to develop new systems and equipment. They were introduced gradually and underwent flight testing in the "Salyut-2, -3, -4" stations. For example, the expansion of the scientific research program depended largely on increasing the capacity of the power supply system. In the first "Salyut" station it was no more than 2 kW. Charging the batteries meant that four rigidly attached solar battery panels had to be oriented on the Sun for about 15 hours per day, which left an extremely limited amount of time for scientific research. After the installation of three panels with an area of 60 m² that were independently orientable on the Sun, the power supply system's maximum capacity was 4 kW. This sufficed even to recharge the batteries of a docked transport ship.

The "Cascade" system was developed in order to realize economical orbital orientation of the station, in an automatic mode, when photographing the Earth's surface and for protracted stabilization during astrophysical investigations.

The successful testing of the new systems made it possible, during the flight of the "Salyut-4" (launched into orbit on 26 December 1974), to expand the scientific program considerably: X-ray sources were investigated, active formations on the Sun were studied, infrared radiation from planets and stars was recorded. More than 4.5 million km² of the USSR's territory was photographed. The materials that were obtained yielded important information on this country's natural resources and are still being used in different branches of the national economy. They have helped us find a deposit of fresh water in the sands of the Kyzylkumy and discover prospective regions for prospecting for oil.

The "Salyut-4" station functioned in orbit for more than 2 years, which naturally inspired optimism. However, a further increase in the service life of orbital stations and the duration of manned expeditions required changes not only in individual systems, but also modernization of the orbital complex's overall layout. This is explained by the following circumstances. The rigid limitations on the station's weight and volume meant that it could carry life support system reserves for no more than 100-120 days of flight of a crew consisting of 2 men. For extended storage of food on board, it was necessary to have a power-consuming refrigerating unit. It was necessary to replenish the fuel reserves periodically. Fresh storage batteries were needed in order to maintain the power supply system at its original level during 2-3 years of station operation.

The units in the telemetry system, the command-signal radio link and a number of other systems were also at the limits of their service lives.

A Second-Generation Station



V.I. Sevast'yanov and P.I. Klimuk in the training mockup of the "Salyut-4" station.

The solution to these solution consisted of the periodic delivery to the station of supplies and fuel, using a special ship. Such a ship would also be able to deliver additional scientific equipment. Besides this, on the station it was necessary to have a separate mooring location where a rescue ship could dock in case of an accident on a transport ship that had delivered a crew to the station. Therefore, in 1973--when the "Salyut-3" and "Salyut-4" were already being built--the designers began working on a station of the next generation, which became the "Salyut-6."

At first it was suggested that the additional docking unit be installed on the station's transfer compartment. However, this would have made its design considerably more complicated. A nonsymmetrical layout of the orbital complex's structure relative to its longitudinal axis would have resulted in additional fuel consumption during operation of the control system. After a detailed analysis, a plan was chosen that featured two docking units located at the ends of the orbital unit. When discussing the station plan, however, there arose the danger that the new layout would prove to be unfit for use. The reason for this follows.

During the process of a ship's approaching the second docking unit, an "incident wave" effect spreading throughout the entire length of the orbital complex could arise. As a result of this, the loads in the first joint between the station and the ship would be several times greater than the permissible level. The danger was quite serious, and it placed in doubt the idea of creating a multiunit orbital

complex based on docking units that had already proven themselves quite well. Nevertheless, a solution was found. Rigidity between a ship and the station was insured by "tightening" the joint with basic and reserve complexes of hooks in the active and passive docking assemblies. The viability of the new plan was tested in January 1978, when the manned "Soyuz-27" ship docked with the "Salyut-6"- "Soyuz-26" orbital complex.

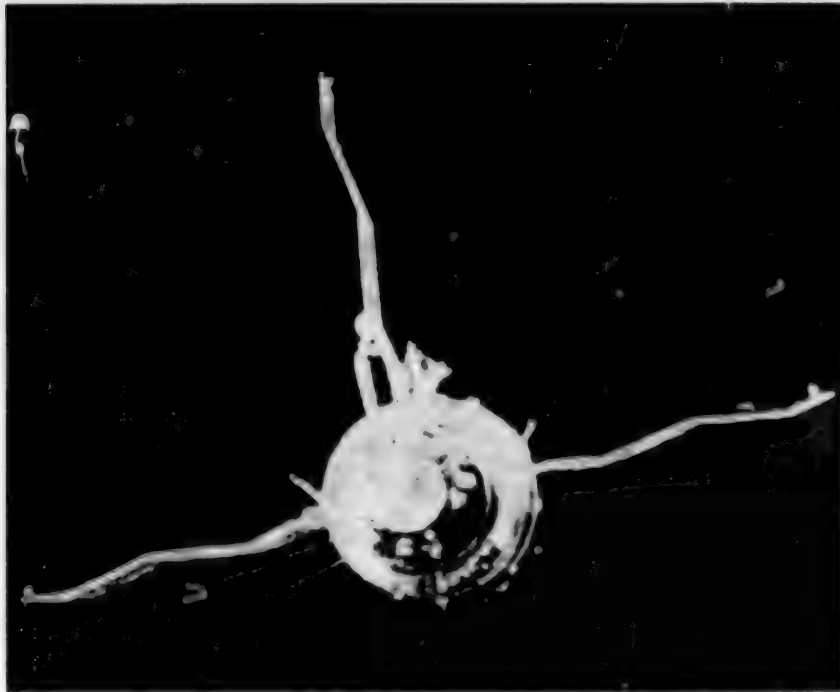
Much work had to be done on a propulsion system that could be refueled in flight after a cargo ship docked at the station. The fuel tanks and the compressors for preliminary evacuation of the gasses from the oxidizer and fuel tanks before re-charging were fundamentally new units.

It is difficult even to compare the "Salyut-6" to the first station, since almost all the service systems have been reworked and part of them are new. In order to extend the operating period, a capability for repairing the power supply, telemetry, television, communication and other systems has been provided. A special complex of instruments was developed for performing repair and maintenance work in weightlessness. In order to increase crew safety during a flight, a compartment pressurization monitoring system was installed, special fire extinguishers were added, and a fire detection system was created. The facilities providing the crew with comfortable living conditions were supplemented. An important place among these is occupied by the introduction of a shower unit. Part of the design's systems and elements were improved for the purpose of eliminating excess weight. The most substantial reworking was that of the temperature regulation system, which made it possible to remove the station's internal heating circuit for a gain of about 100 kg. Only the heat generated during the operation of the on-board systems is now used to heat the living quarters.

The new-generation "Salyut-6" station, which was injected into orbit on 29 September 1977, combined in itself the capability of manned flight and, because of the modern equipment with which it was equipped, that of a research laboratory.

Astrophysical research was conducted on the "Salyut-6" with a BST-1M submillimeter telescope, which has a mirror 1.5 m in diameter. When the telescope is in operation, it is necessary to maintain the temperature of the radiation receivers at 4.2 K. It was necessary to create an on-board low-temperature thermostating system (a piston compressor and two gas-operated refrigerating units). In the future, this system can be used to conduct various experiments in space that require super-low temperatures.

Electromagnetic oscillations from outer space were received by a KRT-10 radio-telescope (ZEMLYA I VSELENNAYA, No 4, 1980, pp 2-9). In addition to its scientific value, the work with the telescope was also of importance practically. The radio-telescope was assembled by the cosmonauts from several units that were delivered by a cargo ship. The supporting platform was the surface around the docking assembly hatch in the transfer chamber. This provided high accuracy in the installation of the telescope's antenna and made it possible to separate it from the station subsequently. The development of the way the 10-m mirror opens will serve as a good basis for the creation of the large but light designs that will be needed in the future for the construction of optical and radiotelescopes tens and even hundreds of meters in diameter. The assembly of such objects is impossible without special facilities to enable man to work in open space. Therefore, one extremely urgent



The "Salyut-6" station in orbit.

matter was the testing on the "Salyut-6" of pressure suits of the semirigid type that would enable a man to work outside the station for several hours.

Yet another important experiment was related to structural "fatigue" caused by the imposition of repeated cyclic loads. They appear because of the activities of the cosmonauts on the trainers and the operation of the engines. As long ago as the first "Salyut" station, the cosmonauts noticed oscillations in the solar battery panels when they were exercising on the "running" track. It was established that the reason for this was coincidence of the running speed with the natural oscillation frequency of individual elements in the design, which caused resonance to appear. After the running rate was changed from the resonance speed the oscillations disappeared, but a fatigue factor appeared that built up as the number of structural load cycles increased. Man has learned how to deal with this in aviation, but this was the first time it had been encountered in space technology. It was necessary to conduct experiments that made it possible to determine the actual loads on particularly critical elements in the station's design.

A great deal of attention was devoted to technological experiments on the "Salyut-5" station, and there were even more of them on the "Salyut-6." In order to perform them, it is true, it was necessary to solve quite a few problems. In the "Alloy" unit, the temperature reached 1,000°C when composite materials were being obtained. An interesting solution was found to the problem of discharging the heat from the space furnace. The unit was made exactly the same size as a container for wastes.

When it was in operation, it was placed in one of the lock chambers and, with the help of a radiation emitter, the heat was discharged into space. The "Evaporator" installation, which was used to apply special coatings, functioned analogously.

Hundreds of "space smeltings" have already been performed. It has been demonstrated that a high vacuum and weightlessness can be used as the necessary medium for obtaining new and unique alloys, crystals and semiconductors in the future. It goes without saying that even at a very early stage there was much talk about the industrial production of new materials in orbit. In order to do this it is necessary to have units with a capacity of several kilowatts that make it possible to carry out the melting process highly accurately. There are many problems involved, but the work that is now being done will undoubtedly help us find a way to solve them.

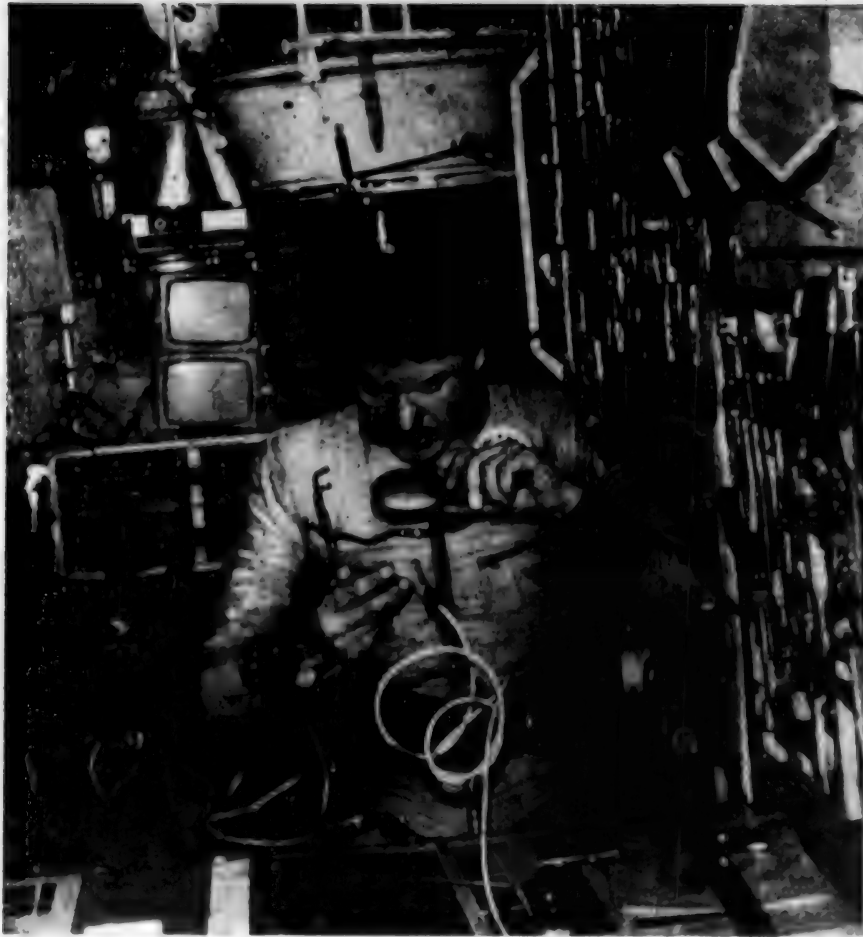
For the conduct of geophysical experiments, the ship was equipped with optico-electronic instruments and photographic gear. The basic part of this equipment had been tested operationally in previous stations. A new instrument that was installed in the station's largest window was the MKF-6M camera for multizonal surveying of the Earth's surface in six bands of the spectrum (ZEMLYA I VSELENNAYA, No 2, 1977, pp 10-15). The quality of the photographs depends essentially on the state of the optical surfaces of the glass used in the station's windows. In order to insure a stable temperature between the photographic equipment's lenses and the window glass, it was necessary to provide additional local ventilation and to install an openable protective cover on the outside of the window.

Among the numerous biological investigations carried out on the "Salyut-6," it is necessary to mention the experiments in which the possibility of the future creation of systems for providing cosmonauts with food, oxygen and other needed components was studied (ZEMLYA I VSELENNAYA, No 6, 1980, pp 20-25). Systems operating on biological principles will be able to supplement the other life support facilities in the future.

The Future of Orbital Stations

In the "Basic Directions for the Economic and Social Development of the USSR for 1981-1985 and the Period to 1990," it says that "the further study and conquest of space in the interests of science, technology and the national economy" is necessary. In the very near future we will be faced with the problem of the maximally efficient and economically justified operation of manned orbital complexes. The role of man in space is becoming more and more significant. A major part of all the experiments performed on the "Salyut" stations were carried out with direct participation of the crew. In addition to operations for controlling and monitoring the on-board systems, on the "Salyut-6" the cosmonauts performed repair and preventive maintenance work, ranging from the simple installation of individual small units to the replacement of hydraulic units in the temperature regulation system. Without such work it would have been impossible for the orbital complex to operate for as long as it did. In some cases the cosmonauts' activities determined the fate of the station, as happened in August 1979 when V.V. Ryumin went out into space in order to free the docking unit on the service module side from the radio-telescope's antenna, which had gotten tangled up with it.

On the "Salyut-6" man overcame the half-year barrier for the duration of work in space. However, a man's sojourn in space on board a spacecraft requires special



The possibility of repairing and replacing equipment contributed to the extended operation of the "Salyut-6" station. V.V. Ryumin repairs a cable.

equipment and more than 10 kg of replaceable life support system elements every day. The latter fact was the basic determining factor of the periodicity of launches of "Progress" cargo ships. Therefore, the search for a rational way of supplying the crew is a problem that is no less urgent than a further increase in the duration of manned flights.

The rhythm of life in orbit took shape gradually. Every flight meant some new adjustments and, speaking bluntly, optimistic predictions. On the first station an 8-hour working day--as on Earth--was planned for the crew. Actually, however, no more than 4-5 hours remained for the performance of the basic work: much time was spent on carrying out sanitary and hygienic procedures, eating, radio communication and the reception of radiograms.

Before "Salyut-6" cosmonauts lived on "orbital" time, or sliding days, which had a negative effect on their well-being. After the first "Salyut-6" expedition it turned out that even the introduction of a set daily cycle was inadequate and it was necessary to have a 5-day work week with 2 days of rest instead of one and the sleeping and physical exercise periods had to be lengthened. Besides this, the program for an extended flight specified periodical medical examinations of the crew. Several days during each expedition were spent on maintenance of the station's systems.

The cosmonauts spent much time installing equipment that was delivered and packing used units in the cargo ships. System maintenance operations, housekeeping and the performance of repair and preventive maintenance work came to occupy a large percentage of the time. Thus, as the duration of the manned expeditions increased, the proportion of working time available for the conduct of research and experiments decreased. Therefore, additional measures to give to crew more actual working time were instituted even as the flights continued. For example, the complicated and laborious operation of refueling the propulsion system was eventually performed without any actual crew participation.

Cardinal measures encompassing several areas are needed in order to increase the crew's working efficiency. One of them is intensification of the scientific research and experiments through the rational distribution of functions between man and machine. The installation of the "Delta" equipment (including an on-board digital computer) on the "Salyut" station was the beginning of the automation of the separate processes involved in controlling and monitoring the state of various systems. On the first station the computer was used for making navigational measurements and computing ballistic parameters. Its functions were expanded on the "Salyut-6." It should be mentioned here that the first steps taken in the use of computer technology on an orbital station were very difficult ones. The microelectronics reacted badly to simultaneous operation with such energy-consuming systems as communications and television. For further development in this field it is necessary to have not only reliable, high-speed computers with large memory capacities, but also considerable modernization of the service systems. The introduction of computer technology and the installation of microrobots will make it possible to automate a whole series of processes in an orbital complex. However, we should not have any special illusions concerning complete automation of all processes. The enthusiasm for automation can lead to extraordinary complexity and, consequently, a lessening of equipment reliability. Terrestrial practice convinces us of this.

In order to improve the economy of operation of manned space complexes it is necessary to reduce the amount of cargo delivered into orbit for the purpose of supporting the station's operation and the crew's activities.

Let us return to the "Salyut-6." "Progress" ships delivered more than 20 tons of cargo to it in 12 trips. Of this cargo the greater part was life support system supplies and units, fuel and replacement units for on-board systems. The consumption rates were clearly not very productive, but how could they be reduced? In the first place, this can be accomplished by changing over to new life support systems operating on a closed cycle (ZEMLYA I VSELENNAYA, No 6, 1980, pp 20-25). This will make it possible to eliminate completely the delivery of water and atmospheric purification supplies to a station. One such system, for regenerating water from condensed atmospheric moisture, has already functioned successfully on board the

"Salyut" stations. For example, during the manned expeditions in the "Salyut-6" station, it was used to produce more than 500 liters of drinking water. A second way of reducing the amount of supplies that need to be delivered into orbit is to reduce the reserves of fuel required for station orientation. This can be done by installing an electromechanical orientation system. Some steps in this direction were made as long ago as the "Salyut-3."

In the future, long-lived orbital stations will be called upon to solve urgent terrestrial problems. Materials produced on Earth are far from perfect. The results of technological experiments conducted in orbital stations give us grounds for hoping that the conditions encountered in space will have a positive effect on the structure and optical and other characteristics of materials. This will open prospects for the creation in a near-Earth orbit of automated industrial complexes having an energy capacity of tens of kilowatts.

Medicine always has a lack of superpure vaccines and other medications, the production of which is quite complicated under terrestrial conditions. There is an assumption that their production in space will be less laborious. For example, this applies to the production of medical preparations by electrophoresis. There is a possibility that in the future we will see new objects in space that are pharmaceutical factories for the production of effective medicines.

The limited nature of the fuel reserves on Earth is already being felt. The energy reserves in space are inexhaustible, because the Sun is capable of providing it for billions of years yet. Naturally, there has arisen a need for its active utilization on Earth. This is possible, in principle, with the help of a solar electric power station operating in a geostationary orbit. The mass of such a power station that is equivalent in output to, say, the Krasnoyarskaya GES, is estimated to be tens of thousands of tons. The problem of creating such a vast structure in space is probably of an order of difficulty greater than other projects, but our need for power has forced us to think about solving it.

These are just a few of the prospective programs, the road to the practical realization of which is already being traveled by the "Salyut" orbital stations.

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LT GEN AVN TITOV ON 'SALYUT-6' PROGRAMS

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 8, Aug 81 pp 40-41

[Article by Lt Gen Avn G. Titov, Hero of the Soviet Union, USSR pilot and cosmonaut:
"The Extended Life of 'Salyut-6'"]

[Text] A program of manned space flights of long duration has been completed by Soviet cosmonauts on the orbital scientific research complex "Salyut-6" - "Soyuz", as well as flights by international crews participating in the "Intercosmos" program.

The CC CPSU, the Presidium of the USSR Supreme Soviet and the USSR Council of Ministers noted the following in their welcoming remarks to scientists, designers, engineers, technicians, workers and cosmonauts, and to all the collectives that participated in the preparation and conduct of the flights: "This new success of cosmonautics in our native land contributes significantly to accomplishing the tasks of the 11th Five-Year Plan regarding the further study and conquering of outer space in the interests of science and technology and the national economy that have been assigned by the 26th CPSU Congress."

Lt Gen Avn G. Titov, Hero of the Soviet Union, USSR pilot and cosmonaut, discusses this program.

The fortune of the "Salyut-6" space station has been amazing indeed. No other manned spacecraft has lived such an intense, restless, long life. Injected into near-earth orbit about four years ago, "Salyut-6" long ago surpassed its designated term of service. Interchangeable crews and regular supply flights by unmanned spacecraft have permitted extension of the space laboratory's service life, and provided the opportunity for replacement and repair of equipment during flight. The station has already received 30 manned and unmanned spacecraft, which have delivered on board 16 crews--eight of which were international--and about 30 tons of diverse cargo.

Actually, the original plans for operations on board "Salyut-6" envisaged only three basic expeditions. But it was precisely this third expedition which, over the course of its record 175-day flight, extended the life of the station. Preventive repair work accomplished by V. Lyakhov and V. Ryumin enabled a fourth, unscheduled 185-day expedition to be sent there. Not only did cosmonauts L. Popov and V. Ryumin

accomplish a great volume of scientific research and host the visits of four crews, but they also contributed significantly to further extending the operational efficiency of "Salyut-6." Next came the flight of L. Kizim, O. Makarov and G. Strekalov. Along with conducting experiments on their own ship, they thoroughly checked out the condition of the station's on-board systems and living compartments, replaced and repaired essential equipment, and effected final preparation of the space dwelling for receiving its fifth basic expedition.

The flight of "Soyuz T-3" basically completed the flight development program for the new ship, which is intended to service orbital stations. After a while, our meritorious space worker "Soyuz" will give way to its younger, more sophisticated brother. Outward appearances may be similar, but the "Soyuz T" has a different "stuffing." Here we see more sophisticated electronic equipment and the application of more efficient design considerations. The ship's guidance circuitry includes a computer system. The sustainer engine and the engines used in docking and orientation are fed from the same fuel cells. As a result of all the innovations, a fairly sizable gain in weight is achieved that allows three cosmonauts in space suits to fit into the ship. If only two are flying the mission, they can take along an extra hundred kilograms of payload. The flight of "Soyuz T-4," which delivered V. Kovalenok and V. Savinykh, the fifth basic "Salyut-6" expedition crew, to the station may be considered the new spacecraft's maiden voyage.

Man's emergence into outer space is a natural process in the evolution of intelligent life. Space affords us unique conditions for conducting various kinds of research and experimentation. Weightlessness, for example, provides us with especially favorable opportunities as regard certain technological processes. It is very difficult to create such conditions on earth, sometimes even impossible.

Space technology is still a young branch of research, yet it is already bearing fruit. Substances with new properties have been created in the electronic heating devices of the "Salyut-6" station which would be entirely impossible to obtain under terrestrial conditions, as well as sensitive elements for electronic instruments whose manufacture is extremely complex and expensive on earth. A number of materials requisitioned by industrial organizations were obtained in the electronic heaters. Orbital station crews tested variants of vaporized metal coatings under conditions of weightlessness. These projects show great promise--it will be possible in this way, for example, to return surfaces to their original condition which have lost certain characteristics as a result of the prolonged effects of space flight factors.

Although the earth's atmosphere maintains life on our planet, it absorbs a great deal of valuable information coming to us from the far and near reaches of the universe. Only telescopes positioned in space are capable of receiving this information in its pure form. The BST-1M sub-millimeter telescope capable as well of operating in the infrared range, has been mounted on the "Salyut-6" space station. The small, portable "Yelena" gamma-ray telescope arrived with one of the cargo ships, followed by the KRT-10 radiotelescope, which operated in conjunction with a ground-based 70-meter telescope for about a month.

The altitude of space orbit also affords us wonderful opportunities for studying our planet. K. E. Tsiolkovskiy wrote that man is acquiring a universal ocean, given to

him purposely, as it were, in order to unite people into a single whole, into one family. He correctly proposed that the conquest of outer space can be achieved most efficiently through the combined efforts of all mankind.

The "Salyut-6" station paved the way for international crews to journey into space. Thanks to the Soviet Union's unselfish assistance, the first space flights of citizens of Czechoslovakia, Poland, GDR, Bulgaria, Hungary, Vietnam, Cuba, Mongolia and Romania were achieved.

The scientific program of each international flight always takes into account national economy-oriented tasks. Hungarian scientists, for example, set up experiments related to the study of materials in space with the aim of being able to utilize the results later on earth for improving the technology of continuous casting of steel. Sugar plays an important role in the Cuban economy. Experiments with it were therefore included in the program for the Soviet-Cuban space flight. Experts believe that a thorough study of the processes involved in saccharose formation under varying conditions, including in space, will enable the technology of its production on earth to be perfected.

All countries express a keen interest in studies of their own natural resources, and in the study and protection of the surrounding environment. But for this common area of concern too, particular national features are always taken into account. Let us take Vietnam as an example.

American aggressors, attempting to crack the resistance of the heroic Vietnamese people, exhibited no shame in choosing their means--not even refraining from the use of chemical weapons. This led to the destruction not only of people, but of everything living as well in the sectors that were hit, and poisoned the soil for years to come.

The government of the Socialist Republic of Vietnam has been taking all necessary measures to eliminate the war's consequences in the most rapid fashion. Man can, and must, help nature quickly heal the wounds incurred by war. With this aim the Soviet-Vietnamese space crew made observations and took photographs of large tracts of forest in the Central Plateau and certain provinces that had been subjected to chemical agents.

Experiments begun by one international crew have frequently been continued by Soviet cosmonauts and by cosmonauts of other socialist brotherhood countries.

Space technology and the results of space research are being widely utilized today in the national economy. The first "Salyut-6" crews operated the station quite intensively, accomplishing purely scientific as well as applied-science tasks--those related, for example, to the search for useful minerals, protection of the surrounding environment, rendering assistance to the commercial fishing fleet and to the lumber and agricultural industries. But the service life of the station's systems and its scientific equipment is, of course, not unlimited. The third basic expedition had to devote a significant portion of its time to repair and restoration operations. Naturally, this lowered the effectiveness of the cosmonauts' scientific work. Perhaps it would be better to replace "Salyut-6" with a new station, where the crew would not be required to monitor so thoroughly the status of on-board systems, or spend time replacing equipment? But of course we intend to continue in the further conquest of

outer space. It is not simply new space stations that we need, but more sophisticated ones. In the long run these will be those very same "ethereal cities" that K. E. Tsiolkovski dreamed about at the beginning of the century.

Certainly there is no single device, no single mechanism which can sustain uninterrupted operation over the course of many years--not to mention decades. Therefore, it is necessary to learn how to service such stations, how to forestall and eliminate faults and disrepair in the operation of their systems.

For the first time, the "Salyut-6" station made it possible to make judgments as to equipment wear and tear without relying on indirect telemetric indications, but through the results of laboratory analysis of instrumentation sent back to earth. Although on-board systems undergo development on experimental testing rigs, it is impossible on earth to duplicate fully the conditions of space flight, the most important of which is weightlessness. Space technology distinguishes itself from other varieties in that experimental testing of the space vehicle goes on simultaneously with its operation. "Salyut-6" is currently of tremendous interest to designers. The results of such extended testing under realistic operating conditions will help make the orbital stations more reliable and more durable; consequently, their effectiveness with regard to the needs of the national economy will be increased. Also, that which was found to remain in a state of good technical repair for the entire duration of "Salyut-6" shows the correctness of the path chosen in extending the active life of the station.

It is well known that man's presence on board the space vehicle expands the opportunities for scientific research considerably. But prolonged exposure to the condition of weightlessness without taking special preventive measures has an unfavorable effect on the cosmonaut's body.

Man emerged and has been living and developing under conditions of earth gravitation to which he is accustomed. These conditions have molded for man a fully defined power framework--his skeleton and a fixed muscular system conformable to his way of life. The human body must constantly overcome the effects of the force of gravity, transfer loads, and expend great energy resources for the functioning of man's support and movement mechanism. Nature does not allow excesses. In the condition of weightlessness, our skeletal fortress turns out to be superfluous, as does the power of our muscles. Post-flight analyses show a reduction in calcium content of the osseous tissues, a change in water and salt metabolism, and a certain decrease in the body's red blood corpuscles and hemoglobin.

The "Salyut-6" space station has effective means at its disposal to prevent the influence of weightlessness on the human body--physiological trainers, special load-training suits, and devices that can deceive the body for a certain period of time, creating the illusion of terrestrial conditions for the cardiovascular system.

One of the most important preventive measures which can influence a crew's operational efficiency is psychological support. Although arctic winterers at the first "North Pole" stations never left their native planet, it is quite possible that they felt more cut off from earth than the "Salyut-6" crews. Regular radio and television communications sessions with relatives and friends, with actors, scientists and sports figures improve the spirits of the cosmonauts, and favorably affect their

same of mind. The live exchange with people on the ground became more effective when a two-way television communications link went into operation.

Procedures for effecting preventive measures are constantly being perfected. The entire experience of Soviet cosmonautics shows clearly that our scientists are on the right track in this regard.

It has already become commonplace for cosmonauts to accustom themselves to weightlessness fairly easily, and to return to the world of earth gravitation without any particular difficulties. Valeriy Ryumin accomplished in succession two of the most prolonged flights in the history of cosmonautics, the interval between them being only seven-and-a-half months. When he and Leonid Popov were queried after their 185-day orbital tour of duty as to how they would react to the proposition that they be sent out into space once again to work at the station, both replied: "If there is an interesting program of research, we'll go."

Repeated flights enable the cosmonauts to adapt to weightlessness far more easily. In addition, work habits acquired during previous flights permit them to execute--literally from the very first days--practically any task in the scientific research program. It is especially significant that these habits can be handed down to their younger colleagues who are experiencing actual space flight conditions for the first time.

Twenty-seven persons have spent time on board "Salyut-6." V. Ryumin, Yu. Romanenko, O. Makarov, V. Dzhanibekov, V. Kovalenok and L. Popov were twice sent to work on board. For 14 of the Soviet cosmonauts, the flights to this space station were their second or third space flight experience.

The first flights of Soviet cosmonauts on the "Vostok" and "Voskhod" space vehicles were a kind of reconnaissance of space. At that time everyone was interested in the question--will man be able to live and function under conditions of space flight? Since then, however, we have progressed from survival-oriented experiments in orbit to the stage where we are settling down in near-earth space. Right now, in light of decisions of the 26th Party Congress, a profitable return is all the more required of cosmonautics in the interests of science and technology and the national economy.

The establishment of a system of supplying orbital stations that includes both manned and unmanned spacecraft, the expansion in duration of the basic expeditions, the development of international cooperation in orbit, and the ever more pronounced effects of space research and experimentation upon the national economy all testify to the fact that cosmonautics as a whole is being transformed into a sector of our country's national economy.

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HOLOGRAPHIC EXPERIMENTS IN SPACE

МНОГОМ АВИАТСІЯ І КОСМОНАВТИКА in Russian No 11, Nov 81 pp 42-43

Translated by Dariusz DE PRYMA - Mathematical Sciences Professor (L. Jurek)

(Abstract) The holographic method is of particular value in cosmonautics. It is actually very important to gather a large amount of information within a short time on board an orbital station. The information content per exposure increases and it becomes possible to obtain three-dimensional or phased information.

There is still another advantage to this technique. The performance of a series of experiments by the station crew requires continuous participation and monitoring by specialists in a narrow scientific discipline and by technicians on Earth. Their activities can undoubtedly be enhanced if the image transmitted by television is three-dimensional.

Experiments conducted on board the Salyut-6 station by cosmonauts V. Kovalenok, V. Davinykh, V. Dzhanibekov, and Zh. Gurragchaa were meant to demonstrate the suitability of the holographic and television equipment and the efficiency of the method. An incidental task was that of obtaining new scientific data. When techniques worked out on Earth and in space are used, the problem can be formulated in the following manner: an experiment is conducted in a space laboratory and the data obtained are holographed at several predetermined times. The holograms are transmitted over a television channel to a ground station. Such transmission is possible during and immediately after the experiment. While it is in progress, specialists can regulate the process involved on the basis of its preliminary results. We can also preclude operation in the opposite direction, i.e., immediate transmission of a three-dimensional representation of a standard object located on Earth to the station for comparison with an object obtained as a result of an experiment or located on board.

The "Hologram-1" experiment was divided into three parts: on-board holography, transmission of the hologram to Earth over a television channel, and transmission to the orbital station. It required a setup with a high degree of protection against vibration and disturbances of system geometry. In point of fact, a displacement amounting to a fraction of a micron during exposure can completely destroy the holographic information. A holographic apparatus of the type in question was developed and built by the staff of the Physicotechnical Institute of the USSR Academy of Sciences. Its mass is less than 1 kg and it is capable of operating under conditions

to severe vibration, e.g., in a moving machine. The light source is a Soviet-produced LG-78 helium-neon laser. A test subject and a sodium chloride crystal are incorporated into the apparatus.

It was decided to investigate the solution of a crystal. The requisite preliminary work was carried out on Earth. Cuban specialists played a significant part in preparations for the portion of the experiment related to transmission of the holograms by television. They made holograms of test subjects and adjusted the systems used to project them into the on-board television camera and photograph them from the station's video monitoring equipment. In addition, they proposed circuitry and developed a system for holography of objects of Earth and projection of the holograms into a television camera at the Mission Control Center for transmission to the station. Soviet specialists also participated in this work.

Another experiment that was devised was "Hologram-2", which was intended to produce a three-dimensional image of the outer surface of a viewpoint bearing pits and cracks formed as a result of bombardment by cosmic microparticles. In order to accomplish this, an attachment intended for holography by the method developed by the Soviet physicist Yu. Denisyuk was built.

On 21 Mar 81, cosmonaut V. Savinykh tested the operation of the holographic apparatus installed in the station during the flight made by L. Kizim, O. Makarov, and G. Strekalov. On the morning of 27 Mar, when the Salyut-6 was in Earth's shadow (it was necessary that there be no external light), V. Kovalenok and V. Savinykh fitted the apparatus and its attachment to the viewpoint and made two preliminary holograms in order to determine the optimum exposure time and the influence of vibrations produced by the fan motor on image reproduction. At 12:00, preparations were begun for holography of the test subject and the process of crystal solution. The solution time for the crystal on Earth was 20-25 min. It was anticipated that solution would take place less rapidly on board Salyut-6, so that a total of 45 min was allotted. It was found that the crystal did not decrease in size in water, even though the entire experimental period was utilized. The cosmonauts received permission to change the film and continue the experiment. However, the crystal did not become perceptibly smaller during exposure of the second film. An experiment conducted on 18 Apr established that there was no noticeable decrease in crystal size over a period of less than 4 h. An unexpected result of great scientific and practical significance for research and work in space was therefore obtained.

The attachments built by Cuban specialists for projection of the holograms on the television camera and photography of holograms from the on-board video monitoring system were mounted at the same time.

The cosmonauts transmitted holograms of 11 different objects. They were photographed at the Mission Control Center. Holographic images were transmitted from the Mission Control Center to the Salyut-6 station during the next communication sessions. A "test" apparatus was first used to produce interference fields from holograms of five objects for projection onto the photosensitive transmitting-tube surface of the television camera. The video signal was recorded on magnetic tape. A test table was recorded for focussing and adjustment of the equipment before the main imaging process was carried out. During the television-communications period,

the video signal was transmitted to Salyut-6 and reproduced by the on-board video monitoring system in the form of holographic images. These were photographed by cosmonaut Zh. Gurragchaa.

On 28 Mar 81, V. Kovalenok and V. Savinykh repeated the "Hologram-2" experiment.

It was thus shown that holographic experiments can be conducted on an orbital station. The small vibration-proof unit operated well. For the first time, holograms were obtained in space and used for reconstruction of the image of an object on Earth. It was shown that current terrestrial observation of experimental results and holographic encoding of images to be transmitted by television are wholly feasible. This means that new opportunities have opened up for research in space, permitting monitoring of the status of individual station components and of the course of physicochemical, medical-biological, and other types of experiments.

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OPERATIONS AT FLIGHT CONTROL CENTER

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 12, Dec 81 pp 40-41

[Article by A. Militsin, flight control center chief]

[Text] Every time a space vehicle is launched a feeling of elation seizes the collective at the flight control center. Interesting and creative work gets underway. It brings new discoveries, new joys. But at the same time it also brings the alarms. The flight will show whether the center made the right decisions about the tasks set and whether it will be possible to find a way out of the complex situations that could arise.

As a rule, the launch is the culmination of one stage of operations and it marks the start of another. The first starts with the design of the space vehicle and, speaking metaphorically, it is our collective that gives birth to a new flight control center. For, whether it is a transport or a freight vehicle, an orbiting interplanetary station or a space equipment system, whatever the case, new means and principles of control are required. Their design, development and introduction form the basic subject of concern for our specialists. The ballistics experts calculate trajectories, the controllers plan the flight program, the mathematicians derive the algorithms and write the programs, the communications people and computer specialists select and introduce new technical and computer equipment. Then comes training for personnel and the equipment. Coordination, mutual understanding and the ability to work out decisions reliably, on an operational basis and under any conditions, are developed. Appropriate situations are modeled on special simulators or played out by leaders in particular or comprehensive training sessions. Thus, the flight control center prepares for the flight.

For us the transfer from the first to the second stage is not instantaneous but a definite period that starts several days before the launch and culminates in the injection of the space vehicle into orbit. At this time, as throughout the entire subsequent flight, the communications network with its television, telephone and telegraph channels firmly and reliably links the center with the launch center, the search-and-rescue complex, all the tracking stations on the territory of the USSR and on the world's oceans, and with the other organizations participating in flight support. There are hundreds of these channels.

During communications sessions a constant stream of trajectory parameters for the movement of the launch vehicle and later the space vehicle arrives in the flight control center, along with data on the operation of tracking station equipment, onboard systems, the state of health of the crew and television information. At the same time, control commands, instructions on action procedures in various situations and ballistic data are being transmitted from the center to the ground and onboard systems and it is in accordance with these that the tracking of the space vehicle is organized. Operations with the crew are strictly regulated; television information is frequently transmitted to the cosmonauts. In addition, the flight control center specialists are listening virtually nonstop to the reports and passing on instructions to personnel at the tracking stations and other organizations providing flight support. The flight control center is the main element in an automated flight control system for a given type of space vehicle; the system consists of data computing complexes, communications centers and a data mapping system.

The ballistics data computing system is the first to go into operation. It computes an accurate launch time and expected orbit injection parameters. Several minutes after the launch of the launch vehicle the ballistics experts obtain estimate data on the actual orbit of the vehicle. And again after 10 or 15 minutes they give a prediction of ballistic time for the life of the space vehicle and proposals for orbit corrections. They also determine the coordinates of the landing area in the event of a urgent reentry. During the flight process the ballistics data computing complex provides the input data needed to organize the operation of all flight control means. It calculates when and for what period it is necessary to switch on the space vehicle engines, how to orient it in space in order to carry out any given flight task, and how the command and measuring points should track the object so as to maintain reliable communications.

The greatest volume of data received, however, comes from the telemetry data computing complex. For example, each day about 800,000 units of information have been received from the Salyut-6--Soyuz complex and processed. To put it graphically, every second the data computing complex has read the equivalent of the complete text of an edition of AVIATSIYA I KOSMONAVTIKA. Telemetry data are the measurements recorded by sensors; there are several thousand sensors aboard an orbiting station. These data are also processed by the data computing system, simultaneously, without delay. And if it happens that the value of any given parameter monitored by the sensor changes, after 1 or 2 seconds it will be passed on to the specialists with an accurate indication of the time (Moscow time). Processed results are analyzed with the aid of special mathematical programs. Here, a conclusion is also simultaneously made about the operating efficiency of several dozen onboard instruments and systems. Analytical data are arranged in the form of output sheets. On each one (and there are more than 400) data is set out so that the specialists can evaluate it quickly.

Organization of the work of our specialists is set up in such a way that incoming information helps in making the right decisions quickly.

Personnel at the center are located in control rooms and working places for individual functional groups. The leading specialists work in the control room. Suggestions offered by each of them are based on a detailed work-up by the appropriate groups in the premises located adjacent to the control room. Each working place

is equipped with several television monitors for the data presentation systems. At the same time ballistics data, telemetry sheets and television information is also passed in. In other words, data from 150 channels arrive at the inputs of about 500 monitors. A specialist has only to press a maximum of two keys in order to obtain the required data on a display screen.

Reliable work by personnel at the center is inconceivable without finely tuned interaction between staff, the space vehicle crew, and specialists from the other organizations involved in support for the space flight. The on-line command communications consoles serve this end; they provide both individual and collective communications for the specialists. Space flight chiefs pilot-cosmonauts of the USSR A. Yeliseyev and V. Ryumin, the communications chief and duty shift chiefs have direct communication with the crew. As a rule the chief operators are cosmonauts training for a subsequent flight. Their working place is also equipped with television camera transmitters.

The tensest period of work is the communications session. Specialists from the analysis group for the operation of onboard systems, medical backup, ground means, experimental groups and controllers are constantly evaluating the data received. At the end of a session the specialists make their remarks and suggestions. Reports are passed as round robins through the chain of command: specialist to the shift chief of his own group, to the shift leader for the flight. Proceeding from the proposals received, recommendations are worked out to formulate the program for the next communications session and an operations plan for the next 24 hours of the flight.

The specialists from the planning group work out the daily plans for the space vehicle and ground means and the program for the next communications session. For this they use mathematical programs and the technical equipment of the command data computing complex, into which they input all recommendations with the aid of the displays. Computed results for different versions are displayed on the screens, and the computer draws the final version on a plotter. This is the basic planning document for the next 24 hours of the flight. At the same time the programs for transmitting commands during the communications sessions are written and documented on the computer's printers. The computer then assembles them into a single block and transmits them via a special automated command-transmit system to the storage devices at the tracking stations. At the next session these blocks are automatically transmitted to the space vehicle on command from the center.

Experience in operations has shown that all specialists must make provision for nonscheduled situations. It is possible that ground equipment will malfunction, the necessary onboard instrument will not be switched on, or the onboard computer will not receive the data. Accordingly, as a rule several versions of the 24-hour plan and the programs for the communications session are drawn up. Most of them are worked up for the most important stages of the flight program: injection of the space vehicle into orbit, link-up of the vehicle with the station, the landing back on Earth and so forth. If these kinds of situation arise the flight controller will make the decision to switch to the necessary reserve version. On days when the most important stages take place, members of the state commission, the chiefs of a number of ministries

and administrations and official representatives of the design organizations come to the center to be on hand should the need arise for decisions connected with fulfillment of the space program as a whole.

The solemnity of the moment is reflected most clearly in the large screens of the main hall from where the orbital station is controlled. Whereas on some days some of the projectors located behind the screen are at rest, in these periods they are all operating at full power. As a rule the computer complex that controls them operates without malfunction. And even though the information displayed on the screens is the same as on normal days, it seems somehow especially colorful. After the successful completion of the next stage, loud applause is heard in the control rooms. People congratulate and thank each other for their successful work. Naturally, the holiday does not last long. The orbital station, of course, is continuing its flight. And so it requires round-the-clock communications support and its working status must be maintained and the planned experiments carried out.

When a space station is in automatic flight the number of people on a working shift is, of course, less. But the freed specialists still carry on with their work. Some of them evaluate and analyze comments on the operation of onboard systems and draw up recommendations for the space vehicle designers. Others analyze the organization of the control process, finding the "bottlenecks" and drawing up measures to improve control quality. Yet others, taking into account the recommendations of these first two groups, turn their attention to new space objects being born in the design organizations. Against the background of operations at the flight control center, down in its depths they begin to create a new center. Such are the regular working days of specialists at the flight control center.

The program of manned flights aboard the Salyut-6--Soyuz complex has been completed but the collective at the flight control center continues with its labors. Having gained our skills, we will henceforth do everything necessary to make more efficient use of space equipment and justify the high appraisal of our work and make a weighty contribution to solving the tasks put forward by the 26th CPSU Congress.

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FLOW AND SPECTRA OF ELECTRONS IN TRANSITIONAL AREA WITH $E_e = 0.3-3$ MeV,
ACCORDING TO DATA FROM 'PROGNOZ-4' ARTIFICIAL EARTH SATELLITE

Moscow GEOMAGNETIZM I AERONOMIYA in Russian Vol 21, No 3, May-Jun 81
(manuscript received 23 Jan 80) pp 428-434

MINEYEV, Yu. V. and SPIR'KOVA, Ye. S., Institute of Nuclear Physics,
Moscow State University

[Abstract] The "Prognoz-4" satellite carried a differential spectrometer that was used to study electron flows from 11 February to 11 March 1976. During this period, several surges in the intensity of electron flows, which were possibly related to flare activity on the Sun, were observed. The data gathered make it obvious that there is a layer of active electrons in the transitional area, the thickness of which depends on the width of surges right at the magnetopause, inside the transitional area and at the front of the basic shock wave. The nature of this layer is still unclear, but the authors offer several hypotheses that might explain it. Figures 5; references 14: 10 Russian, 4 Western.
[15-11746]

UDC 551.521.8

SPECTRA OF ELECTRONS WITH ENERGY 0.03-3.0 MeV FORMING LAYER IN TRANSITION
REGION ACCORDING TO 'PROGNOZ-4' SATELLITE DATA

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 5, Sep-Oct 81
(manuscript received 16 Jul 80) pp 780-785

MINEYEV, Yu. V., SPIR'KOVA, Ye. S. and SHESTOPALOV, I. P.

[Abstract] The "Prognoz-4" satellite was used in measurements of fluxes of electrons with an energy 0.03-0.5 MeV using an apparatus with two gas-discharge counters (with magnetic filters) directed toward the sun and away from the sun and also in measuring streams of electrons with an energy 0.3-3.0 MeV using a differential spectrometer. The authors therefore studied the experimental

characteristics of the electron layer between the shock wave front and the magnetopause in places of high-latitude intersection of the transition region by the satellite. The thickness of the layer attains several earth radii; the particle intensities exceed the background value by more than an order of magnitude. A comparison of the results obtained by two different methods made it possible to determine the localization of the increases in electron streams in intersections of the layer and also the energy spectra of electron bursts in a broad range of energies 0.03-3.0 MeV. The electron spectra were very different in different parts of the intersection. The "Prognoz," IMP and Geos satellites registered bursts of high-energy electrons both in interplanetary space and in the transition region. Those measurements did not make it possible to ascertain the spectral characteristics of electron bursts in a broad energy range, as well as the maximum energies of bursts. The authors have clarified these problems. Figure 1 shows the projections of "Prognoz-4" orbits in a helioelliptical coordinate system in the XZ plane. Figure 2 shows the temporal profiles of intensities of electrons with E_e 0.03-0.5 MeV, 0.5-0.8 and 2.0-3.0 MeV. Figure 3 shows variations of streams of electrons with energies 0.03-0.5, 0.5-0.8, 2-3 MeV from the entry of the satellite into the magnetosphere to its emergence from it. Figure 4 shows the differential energy spectra of electrons obtained during intersection of the transition region. Figure 5 shows the integral spectra of electrons in the energy range $E_e = 0.03-3$ MeV. The specifics of the properties of the transition region indicate the possibility of acceleration of electrons in the medium in magnetic gradients. Despite the considerable amount of information obtained in this investigation the problem of the nature of electron increases in the transition region remains open. Figures 5; references 12: 10 Russian, 2 Western.
[24-5303]

UDC 521.61:550.388.2

PRELIMINARY RESULTS OF OUTER IONOSPHERE SOUNDING BY 'INTERCOSMOS-19' ARTIFICIAL EARTH SATELLITE

MOSCOW GEOMAGNETIZM I AERONOMIYA in Russian Vol 21, No 3, May-Jun 81
(manuscript received 11 Apr 80) pp 451-456

VASIL'YEV, G. V., GONCHAROV, L. P., KUSHNEREVSKIY, Yu. V., MIGULIN, V. V.,
FLIGEL', M. D. and SHAULIN, Yu. N., Institute of Terrestrial Magnetism,
the Ionosphere and Radio Wave Propagation, USSR Academy of Sciences

[Abstract] The "Intercosmos-19" artificial Earth satellite carried an IB-338 ionosphere station for the purpose of conducting pulsed sounding of the outer ionosphere. The IB-338 operates on 338 fixed frequencies in the 0.3-15.95 MHz band. The authors give a detailed description of its functions, after which

they analyze ionograms made with the help of a standard telemetric system on 7 March 79 from 1417 to 1622 hours Moscow Daylight Savings Time. Their basic attention is focused on the electron concentration in the F2 layer and variations in it. Figures 6; references 7: 6 Russian, 1 Western.
[15-11746]

UDC 521.61:550.388.2

FEATURES OF AMPLITUDE SPECTRA OF WHISTLING ATMOSPHERICS AT FREQUENCIES BELOW 1 kHz ('INTERCOSMOS-5' AND 'INTERCOSMOS-14' ARTIFICIAL EARTH SATELLITES)

Moscow GEOMAGNETIZM I AERONOMIYA in Russian Vol 21, Nov 3, May-Jun 81
(manuscript received 28 Feb 80) pp 457-462

KAPUSTINA, O. V., MIKHAYLOVA, G. A. and MIKHAYLOV, Yu. M., Institute of Terrestrial Magnetism, the Ionosphere and Radio Wave Propagation, USSR Academy of Sciences

[Abstract] The authors present the amplitude spectra of partially dispersed (electron) whistling atmospherics on frequencies below 1 kHz and the spectra of proton whistling atmospherics recorded at different altitudes in the outer ionosphere by the "Intercosmos-5" and "Intercosmos-14" satellites. The recordings underwent digital processing with the help of a digital spectrum analyzer. There is also a discussion of whistling atmospherics that excite extremely low frequency emissions (700-800 Hz). Figures 4; references 10: 8 Russian, 2 Western.
[15-11746]

UDC 550.383

PLASMA-LAYER ELECTRONS IN GEOSYNCHRONOUS ORBIT

Moscow GEOMAGNETIZM I AERONOMIYA in Russian Vol 21, No 3, May-Jun 81
(manuscript received 2 Oct 79, after revision 28 May 80) pp 506-510

IL'IN, V. G., MIKLUKHINA, L. D. and OSIPOV, N. K.,
Krasnoyarsk State University

[Abstract] In order to solve the two-dimensional continuity equation that defines the distribution of plasma in the magnetosphere's equatorial plane, the authors use the method of integration with respect to trajectories. After making several assumptions about the nature of the physical conditions in the

plasma layer, they set up a stationary continuity equation and make numerical calculations with it. One of the basic factors determining the spatial distribution of plasma-layer electrons along geosynchronous orbits is the relationship between the dimensions of the forbidden area and the orbit's radius, changes in which can result in large changes in the electron concentration. Figures 3; references 7: 4 Russian, 3 Western.
[15-11746]

UDC 551.521.8

PENETRATION OF SOLAR PROTONS AND ALPHA-PARTICLES WITH ENERGY LEVELS ABOVE 1 MeV/NUCLEON INTO POLAR CAPS

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 4, Jul-Aug 81
(manuscript received 10 Dec 79) pp 551-558

VLASOVA, N. A., IVANOVA, T. A., PANASYUK, M. I. and SOSNOVETS, E. N.

[Abstract] The authors analyze two instances of solar cosmic ray penetration into the polar caps that occurred 19-22 September 1977 and 13-14 February 1978. Their data were gathered by an SPA-1 proton and alpha-particle spectrometer on board the "Cosmos-900" satellite, which was in a circular orbit at an altitude of about 500 km and had an orbital inclination of 82° . They discuss the temporal intensity profiles, spectral changes and variations in the N_α/N_p flow ratio. The authors then compare their data with measurements made by the "IMP-7 and 8" satellites in interplanetary space. Figures 5; references 20: 5 Russian, 15 Western.
[7-11746]

UDC 551.510.53

ANALYSIS OF MODERN SEMIEMPIRICAL MODELS OF THERMOSPHERE, BASED ON THEORETICAL CALCULATIONS AND INDIVIDUAL ROCKET MEASUREMENTS OF ATOMIC OXYGEN

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 4, Jul-Aug 81
(manuscript received 16 Feb 81) pp 638-641

VLASOV, M. N., DAVYDOV, V. Ye. and LIVSHITS, A. I.

[Abstract] The authors compare the MSIS and DTM semiempirical models of the thermosphere (based on mass spectrometer and incoherent scatter data and satellite drag data, respectively) with a theoretical model and experimental data gathered by the resonance fluorescence and semiconducting detector

methods. The theoretical model is based on the solution of a system of six continuity and motion equations for a three-component mixture of O, O₂ and N₂. The experimental data were gathered by three rockets launched from the United States, the USSR and Great Britain in 1975, 1979 and 1974, respectively. The authors conclude that the thermosphere is affected by solar activity, the time of year, the latitude and the altitude. Figures 2; references 13: 2 Russian, 11 Western.
[7-11746]

UDC 581.521

QUANTITATIVE CORRESPONDENCE OF SOLAR PROTON STREAM MEASURED OUTSIDE AND INSIDE EARTH'S MAGNETOSPHERE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 5, Sep-Oct 81
(manuscript received 30 Sep 80) pp 775-777

KLIMENKO, V. V.

[Abstract] During 1977-1979 the "Raduga" geostationary satellite was used in measurements of integral fluxes of charged particles in the proton energy interval 245; 285; 2130 MeV. A number of increases in the intensity of charged particles associated with solar flares were registered. This article gives a comparison of fluxes of flare particles for the events of 24 September 1977, 7 May 1978 and 23 September 1978 according to measurements inside and outside the magnetosphere. The analysis included data from the following satellites: "Raduga," "GMS," "Prognoz-6", as well as "Venera-11" and IMP-7,8. The particle flux (averaged by angles) outside the magnetosphere is

$$\bar{I}_{out} \approx I_0 \frac{\theta_0^2}{4} \quad (1)$$

From the condition (1) $\sin^2 \theta_0/H_0 = \sin^2 \theta_1/H_1$; $H_1 > H_0$. In the approximation of small angles θ

$$\theta_1^2 \approx \theta_0^2 \frac{H_1}{H_2}. \quad (2)$$

The averaged particle flux within the magnetosphere is:

$$\bar{I}_{in} \approx I_0 \frac{\theta_0^2}{4} \frac{H_1}{H_0} \approx \bar{I}_{out} \frac{H_1}{H_0}, \quad (3)$$

that is

$$\bar{I}_{in}/\bar{I}_{out} \sim H_1/H_0.$$

The experimentally observed ratio $\bar{I}_{in}/\bar{I}_{out}$ for the three mentioned events was ~ 3 , ~ 7 and ~ 5 respectively. It is concluded from conditions (2) and (3)

that in the process of penetration of solar particles into the earth's magnetosphere in a region of a strong field there is an isotropization of the particle flux. A high I_{in}/I_{out} ratio should correspond to a high degree of anisotropy of the stream of solar particles incident on the magnetosphere. Using data from measurements on satellites with spatially separated orbits, by comparison of particle fluxes, it is therefore possible to monitor the degree of collimation of a beam of solar particles in the interplanetary medium. Figures 2; references 10: 3 Russian, 7 Western.
[24-5303]

UDC 581.521

SPECTRUM OF FLARE PROTONS IN LOW-ENERGY REGION

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 5, Sep-Oct 81
(manuscript received 23 Apr 81) pp 704-711

DAYBOG, Ye. I., KURT, VIKTORIYA G. and STOLPOVSKIY, V. G.

[Abstract] It has been experimentally established that at low energies ($E < 1$ MeV) the spectral slope of flare protons (the spectrum is usually measured at ~ 1 a.u.) decreases. Until now it has been assumed that such an irregularity in the observed spectrum is attributable only to ionization losses of protons in the hot plasma of the solar corona. However, the authors feel that this conclusion requires reexamination. A different approach is proposed for explaining the change in the spectral slope of flare protons at low energies. This approach involves allowance for the adiabatic deceleration of protons in the interplanetary medium. Such a study was made using experimental data on the energy spectrum of protons jointly with the times when proton intensity attains a maximum at the observation point in the entire accessible energy range $t_m(E)$. The change in slope in the energy spectrum of protons occurs at approximately the same energies at which the irregularity in the dependence $t_m(E)$ is impaired. The principal basis for the study was observations of bursts of solar cosmic rays in the increase phase of the 21st solar activity cycle in 1976-1979 made with "Prognoz" satellites and "Venera" vehicles. Proton fluxes were measured in the energy range from ~ 0.08 to 150 MeV. The proton spectra were analyzed for 19 events occurring during the considered period. All these events in solar cosmic rays were caused by solar flares in the range of heliolongitudes $\sim \pm 50^\circ$ from the base of the magnetic line of force best connected to the observation point. The energy losses of protons in the interplanetary medium due to adiabatic cooling were estimated. It is shown that this effect is important for protons with an energy < 1 MeV and in the case of not very powerful flares (importance $\leq 1B$) it plays the decisive role in formation of the spectrum of observed flare protons. Corrections to the spectrum of observed protons necessitated by

energy losses in the interplanetary medium make it possible to assume that in the case of not very powerful flares the injection spectrum does not have a change in slope to an energy ~ 0.2 MeV. This indicates that the source of flare protons is situated at depths in the solar atmosphere $\leq 20 \mu\text{g}/\text{cm}^2$. Accordingly, in contrast to the conclusions drawn by R. E. McGuire, et al. in 15th INT. COSMIC RAY CONF., Vol 5, 1977, it can be assumed that the generation of flare protons occurs at the same depths as the generation of flare electrons. Figures 3, tables 2; references 25: 5 Russian, 20 Western. [24-5303]

UDC 581.521.6

RATE OF MOVEMENT TOWARD POLE OF HIGH-ALTITUDE BOUNDARY OF FLOWS OF ELECTRONS WITH $E_e > 0.7$ MeV DURING EXPLOSIVE PHASE OF SUBSTORM

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 4, Jul-Aug 81 (manuscript received 22 Apr 80) pp 647-649

GINZBURG, Ye. A.

[Abstract] Utilizing data gathered by the "Meteor-22" and "Meteor-25" satellites and at auroral stations on the night side of the Earth, the author determines that the movement of the high-altitude boundary of flows of electrons with $E_e > 0.7$ MeV toward the pole is related to the development of polar magnetic substorms. On the basis of data gathered from 12 to 14 December 1979, he calculates the rate of movement to be 0.5 ± 0.2 km/s, but states that this figure is probably low, since the most intensive movement takes place near the midnight meridian and most of the measurements were made at other times. Figures 3; references 2.

[1-11746]

UDC 550.37

ELECTRIC FIELDS CAUSED BY PHOTOELECTRON STREAM

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 5 Sep-Oct 81 (manuscript received 15 Jan 80) pp 773-774

VLASOV, V. G.

[Abstract] Satellite measurements of the difference in electric potentials between magnetically conjugate F regions in the ionosphere by means of a comparison of the spectra of photoelectrons in these regions in the case of an asymmetrical illumination revealed the absence of an electric field with an

accuracy to ± 10 V. Measurements of spectra with a high resolution made it possible to reduce this limit to ± 1 V. The author has therefore reevaluated the potential difference between the magnetically conjugate ionospheric F₂ regions caused by the photoelectron flux under the condition of asymmetric illumination. An evaluation of the total potential difference along a tube of force gives a value ~ 1 V, directed opposite the stream of photoelectrons; in the first thousand kilometers the potential drop is ~ 0.5 V, and in the next ten thousand kilometers is ~ 0.3 V. The stream of thermal electrons caused by the flux of photoelectrons is clearly inadequate even for a buildup of ionocyclotron turbulence in any region of the tube of force. Although high-frequency turbulence in itself does not slow thermal electrons, nevertheless nonlinear processes can lead to the pumping of part of the energy into the low-frequency region, that is, to anomalous resistance. The stream of photoelectrons cannot cause high-frequency turbulence. Accordingly, any anomalous resistance generated by a stream of photoelectrons is excluded. It is evident that the potential difference along a tube of force makes it possible to measure the electric field induced by a stream of photoelectrons if there is a small increase in the resolution of electron counters. Such measurements can yield information on the density distribution of thermal plasma along a tube of force. Tables 2; references 5: 4 Russian, 1 Western. [24-5303]

UDC 623.169

DYNAMICS OF RELATIVISTIC ELECTRONS IN OUTER BELT INSIDE AND OUTSIDE PLASMAPAUSE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 5, Sep-Oct 81
Manuscript received 15 Apr 80) pp 712-717

YERCHURO, I. N. and SHAVRIN, P. I.

[Abstract] The dependence of the density of streams of electrons (EDS profiles) on the magnetic shell parameter L was determined from the results of measurements on two simultaneously operating "Molniya-1" satellites when they intersected the earth's outer radiation belt from $L = 3$ to 6 in January and July 1971 during magnetic storms of different intensity. The article examines the profiles of relativistic electrons of the outer belt in different magnetic storm phases and examines the difference in the character of electron variations inside and outside the plasmapause. The following picture was found. Under quiet geomagnetic conditions the plasmapause is usually situated at $L = 5-6$. This means that a large part of the belt of relativistic electrons is situated within the plasmasphere. With maintenance of quiet conditions over the course of several days the state of the belt of electrons remains virtually unchanged. This is evidence of an equilibrium distribution

of EDS profiles within the plasmasphere, a balance between the injection and loss processes. The outer belt of relativistic particles is concentrated for the most part in the region $L = 3-5$. For electrons in the energy range 1-2 MeV in this region under quiet conditions there is a maximum in the differential energy distribution and anisotropic pitch-angle distributions. During the main phase favorable conditions are created for resonance interaction of electrons with an energy $E_e \sim 1.0$ MeV with ionocyclotron waves near the plasmapause. These waves are generated by a ring current of protons whose density increases considerably during the main phase of the storm. The density maximum of the ring current is situated near the plasmapause on its outer side. With movement of the plasmapause toward the earth the density maximum of the ring current also moves toward the earth, always remaining near the plasmapause, but outside it. Resonance interactions of electrons with an energy $E_e \sim 1.0$ MeV with ionocyclotron waves develop in the entire region of movement of the plasmapause. This interaction leads to a considerable decrease in the lifetime of electrons in the region of movement of the plasmapause and in the region of ring current development. During this period there is a transition from anisotropic pitch-angle distributions of electrons to isotropic and also disappearance of the maximum in the energy range 1-2 MeV in the differential energy distribution. A considerable decrease in the lifetime of electrons, approaching the time characteristic for a strong pitch-angle diffusion, leads virtually to disappearance of the belt of relativistic electrons by the end of the main phase of the storm. In the phase of magnetic storm restoration the density of the ring current decreases and there is an increase in the energy of the electrons entering into resonance interaction with the ionocyclotron waves by several times. For electrons with $E_e > 1.5$ MeV this interaction lessens considerably, which leads to a considerable increase in the lifetime of such electrons and transition to an anisotropic pitch-angle distribution. A "new" belt of relativistic electrons is formed in the restoration phase; it is formed outside the plasmasphere in the region of the maximum density of the ring current of protons. Thus, the processes of interaction of electrons with an energy $E_e > 1.5$ MeV with ionocyclotron waves generated as a result of instabilities of the ring current of protons play a substantial role in the formation of the EDS profiles in different magnetic storm phases.

Figures 2; references 16: 7 Russian, 9 Western.

[M-5303]

CHANGES IN CHARGED PARTICLE CONCENTRATION IN HIGH-LATITUDE IONOSPHERE DURING
MAGNETOSPHERIC-IONOSPHERIC DISTURBANCES IN SEPTEMBER 1977 ACCORDING TO
'COSMOS-900' DATA

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 5, Sep-Oct 81
(manuscript received 22 Apr 81) pp 718-725

GDALOVICH, G. L., VSEKHSVYATSKAYA, I. S., OZEROV, V. D. and SOBOLEVA, T. N.

[Abstract] Several solar flares were observed in September 1977; three of these had an importance not less than 3. During this same period there were three small and one large geomagnetic storms. Data from the "Cosmos-900" satellite on change in the concentration of charged particles, obtained in September 1977 in different phases of development of geomagnetic disturbances, make it possible to carry out an analysis of the influence exerted on the high-altitude ionosphere by processes of ionospheric-magnetospheric interaction. In particular, the intensification of the magnetospheric electric field at the time of a geomagnetic storm leads to a shifting of the middle-latitude ionospheric gap to the low latitudes, with the maximum occurring at the time of the main phase of the storm. An increase in the number and intensity of inhomogeneities and the development of microscale inhomogeneities against the background of more macroscale inhomogeneities during the main phase of a magnetic storm are possibly caused by the generation of low-frequency radiations during interaction of the ring current with the plasmapause. The development of additional gaps in the concentration of charged particles during a period of decay of the ring current is evidence of the influence of leaking at this time into ionospheric plasma (evidently by means of the plasma instabilities arising at this time). The form of the middle-latitude ionization gap is dependent on the phase of the geomagnetic storm. Figures 4; references 8: 2 Russian, 6 Western.

[24-5303]

RESULTS OF MEASUREMENTS OF RELATIVISTIC PARTICLES IN SEPTEMBER 1977 USING
CERENKOV DETECTOR CARRIED ON 'COSMOS-900' SATELLITE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 5, Sep-Oct 81
(manuscript received 7 Jul 80) pp 778-780

GORCHAKOV, Ye. V., IOZENAS, V. A., TERNOVSKAYA, M. V., AFANAS'YEV, V. G.,
AFANAS'YEV, K. G., KLIMOV, N. I. and INDYUKOV, A. Ye.

[Abstract] In order to obtain information on dynamics of intensity of fast charged particles in circumterrestrial space the "Cosmos-900" satellite carried

a global multichannel Cerenkov detector with a large geometry factor. This article is devoted to a description of the data collected by this instrument in the second half of September 1977. During this time most of the period was typical with respect to radiation conditions in circumterrestrial space in the absence of strong magnetospheric disturbances but at the end of the month there was a considerable decrease in the intensity of cosmic rays associated with the Forbush effect. Data are given on the counting rate on 19 September 1977 for channels I, V and X, registering protons, electrons and particles with $Z \geq 2$; these data are typical for a quiet period. The different peculiarities of these data are examined. Certain small intensity maxima in the L interval from ≈ 3 to ≈ 5 are evidently associated either with the outer radiation belt or with albedo particles. For the orbital revolutions intersecting the equator in the range of geographical longitudes -45° - -70° to the south of the equator there are strong intensity maxima associated with the entry of the satellite into the region of the Brazilian anomaly. Near the geomagnetic equator the counting rate for all channels experienced periodic changes each half-revolution. With the satellite transit of the equator from south to north the counting rate was 10-20% greater than with transit from north to south. This phenomenon is attributable to the east-west asymmetry of cosmic rays and the peculiarities of instrument placement aboard the satellite. In late September 1977 the instrument registered a considerable decrease in cosmic ray intensity; details concerning this Forbush decrease are given. Figures 2; references 7: 4 Russian, 3 Western.

[24-5303]

UDC 550.37

GENERATION OF ELECTRIC FIELDS IN TAIL OF MAGNETOSPHERE IN PRESENCE OF CONDUCTING IONOSPHERE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 5, Sep-Oct 81
(manuscript received 26 Mar 80) pp 726-732

PIVOVAROV, V. G.

[Abstract] A study was made of the problem of generation of electric fields and currents in the tail of the magnetosphere under the influence of viscous friction of the solar wind against magnetospheric plasma. The investigation was made within the framework of magnetohydrodynamic equations. The purpose of the study was a clarification of the role of the polar ionosphere in such a mechanism in the generation of electric and magnetic fields. It is shown that the ionosphere is responsible for formation of the structure of ionospheric currents and exerts an influence on the parameters of electric and magnetic fields in the tail of the magnetosphere. Ionospheric conductivity determines the dimensions of the region of return flow in the plasma

layer. The electric field in the tail is directed from evening to morning in the regions adjacent to the solar wind and from morning to evening in the central region. The discontinuity of these regions is also controlled by ionospheric conductivity. The author examines a model which corresponds to quiet conditions in the magnetosphere. It is shown that the hypothesis advanced by W. I. Axford, et al. (CANAD. J. PHYS., Vol 39, p 1433, 1961) that it is important to take viscous friction into account in an investigation of the generation of the electric field in the tail of the magnetosphere is in agreement with the considered model. The inclusion of the ionosphere in the model leads to a number of important consequences: longitudinal currents and ionospheric closure currents appear, the region of a countercurrent always exists, and within the framework of a self-consistent model the extent of this region attains 60% of the entire plasma layer. Figures 1; references 6: 4 Russian, 2 Western.
[24-5303]

UDC 551.521.8

ALLOWANCE FOR ION CURRENT IN DETERMINATIONS OF ELECTRON TEMPERATURE USING CYLINDRICAL LANGMUIR PROBE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 5, Sep-Oct 81
(manuscript received 9 Jan 80) pp 695-703

VAGNER, Kh. U. and IOKHANNING, D.

[Abstract] Satellites of the "Intercosmos" series, like others, have carried Langmuir probes for measuring electron temperature T_e and electron density n_e . These two parameters can be determined from the measured dependence of the current I_g on probe potential U_s . In a case when the probe potential is $U_s > U_R$ (U_R is plasma potential) the electrons are accelerated by the probe and the ions are slowed. When $U_s < U_R$ the probe accelerates ions and slows electrons. The determination of T_e is based on an investigation of the electron current I_e in the region of slowing of electrons, where $U_s < U_R$. With this taken into account, the authors used two different methods in approximate determinations of I_i for processing measurements of the cylindrical Langmuir probe aboard the "Intercosmos-10." A study was made of the influence of the I_i correlation on the resultant values of the electron temperature T_e . The theory of a Langmuir probe moving in plasma gives a complex dependence of the ion current $I_i(U_s)$. Accordingly, it is generally impossible to use the least squares method for determining the coefficients in the equations determining the mentioned theoretical dependence and an unambiguous extrapolation of I_i into the region $U_s < U_R$ is impossible. Figures 5; references 9: 1 Russian, 8 Western.
[24-5303]

ROCKET MEASUREMENTS OF AEROSOL PARTICLE CONCENTRATION AND DISTRIBUTION, BY SIZE, IN THE ATMOSPHERE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 4, Jul-Aug 81
(manuscript received 4 Apr 79) pp 641-645

ORISHICH, T. I. and CHERKASOV, A. V.

[Abstract] The authors present data on the altitudinal distribution of atmospheric aerosols gathered by a photoelectric counter installed in an M-100 meteorological rocket. The data cover eight launches from 1972 to 1978. The authors present the first data on the concentration of aerosol particles of submicron size at altitudes of 20-60 km and find that the altitudinal distribution of the concentration at altitudes of 10-90 km differs from the usually assumed exponential distribution. They also present the first data on the distribution (by size) of particles at altitudes of 20-90 km that were gathered by a single instrument. Figures 2; references 21: 6 Russian, 15 Western.
[7-11746]

UDC 551.510.4

RESULTS OF INTEGRATED MEASUREMENTS OF UPPER ATMOSPHERE'S NEUTRAL COMPOSITION BY 'VERTIKAL'-4' ROCKET

Moscow GEOMAGNETIZM I AERONOMIYA in Russian Vol 21, No 3, May-Jun 81
(manuscript received 4 Feb 80, after revision 23 Jun 80) pp 476-480

KOCHNEV, V. A. and SHYUTTE, N. M., Institute of Space Research,
USSR Academy of Sciences

[Abstract] A "Vertikal'-4" rocket launched on 14 October 1976 to an altitude of 1,512 km carried equipment for the measurement of the upper atmosphere's composition by both the mass-spectrometer and sorption methods. The simultaneous use of both methods improves the accuracy of the results, since the use of either one by itself involves considerable practical difficulties in obtaining reliable data. The authors present the results of the mass-spectrometer and solar radiation absorption measurements and adjust them for several factors. They conclude that the neutral atmosphere is in a state that is close to diffusion equilibrium for a diurnal exosphere temperature of about 750 K, which low temperature was apparently typical for the period of minimum solar activity at the beginning of the 21st cycle in 1976. Figures 4; references 10: 4 Russian, 6 Western.
[15-11746]

STRUCTURE OF TEMPERATURE IRREGULARITIES ON BASIS OF ATMOSPHERIC REFRACTION OBSERVATIONS FROM 'SALYUT-6' ORBITAL STATION

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 259, No 6, Aug 81
(manuscript received 9 Apr 81) pp 1330-1333

GURVICH, A. S., ZAGORUYKO, S. V., KAN, V., POPOV, L. I., RYUMIN, V. V., SAVCHENKO, S. A. and CHOCHIA, P. A., Institute of Physics of the Atmosphere, USSR Academy of Sciences, Moscow

[Abstract] A hand-held 16-mm motion picture camera with a lens having a focal length of 50 cm was used on board the "Salyut-6" orbital station on 26 May 80 to photograph the sunset over the western Pacific Ocean for the purpose of gathering data on the horizontal structure of layered temperature irregularities in the atmosphere. About 5,000 frames were taken at an average interval of 0.8 s. On the basis of an analysis of the film, the authors conclude that such temperature irregularities can range in length from 1 km or less up to 100 km. Figures 2; references 6.
[6-11746]

UDC 621.384.523.72

INVESTIGATIONS OF TWILIGHT LAYER IN EARTH'S ATMOSPHERE FROM SPACE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 5, Sep-Oct 81
(manuscript received 5 May 80) pp 786-790

GRECHKO, G. M., DIVARI, N. B., NIKOL'SKIY, G. M., ROMANENKO, Yu. V. and SAVCHENKO, S. A.

[Abstract] Photographs of the twilight glow were obtained for the first time from aboard the "Salyut-6" in March 1978. In the course of 2 minutes a total of 10 photographs were taken on which it was possible to trace the gradual development of the twilight glow from the nighttime side of the atmosphere to the terminator. The article gives some results of processing of three of these photographs. The photographs were taken from an altitude of 345 km by a camera with an objective $F = 150 \text{ mm}$, 1:4. The region of the earth's atmosphere near the terminator was photographed. The photographs show the twilight glow in the form of a luminescent layer propagating from the daytime to the nighttime side. On the nighttime side there is detachment of the luminescent layer from the apparent horizon. From a comparison of the isophots on the three frames, which were arranged in the sequence of a decrease in solar zenith distance, it is clear that with a change in solar zenith

distance the form of the isophots in the upper part of the luminescent layer does not change: they remain concentric with the earth's surface. However, those parts of the isophots which correspond to the parts of the atmosphere projected onto the earth's surface do change. With a change in the angular distance from the terminator from 0 to 180° (or the angular distance from the sun from 90° to 1080°) the intensity of the primary twilight ray changes by 10 orders of magnitude (from 10^{-5} to 10^{-15} in relative units). In the case of small angular distances from the terminator the lower boundary of the primary twilight ray is situated at a low altitude in direct contact with the earth's surface. With an increase in angular distance from the sun the primary twilight ray rises above the earth's surface and is detached from it so that the isolines form distinctive "whiskers" which are evident on the space photographs. The twilight glow observed from space is the result of the superposing of the primary and secondary twilights. The secondary twilight is the glow of the lower atmosphere caused by scattering of the light of the primary twilight ray in the lower layers of the atmosphere. It is clear that photographic observations of the twilight glow of the earth's atmosphere from space can be used in studying the distribution of matter in the upper layers of the earth's atmosphere and in analyzing the distribution of scattered solar radiation in the earth's atmosphere. In particular, it is possible to obtain important data on the structure of the primary twilight ray and the positioning of the secondary twilight layer. A study of successive photographs taken during the motion of a space vehicle will make it possible to determine the spatial distribution of matter in the earth's atmosphere scattering and absorbing solar radiation. Figures 2; references: 5 Russian. [24-5303]

UDC 551.501.71:551.510.53

EVALUATING DENSITY VARIATIONS IN THE STRATOSPHERE ON BASIS OF OBSERVATIONS OF STELLAR FLICKERING

Moscow IZVESTIYA AKADEMII NAUK SSSR: FIZIKA ATMOSFERY I OKEANA in Russian Vol 17, No 8, Aug 81 (manuscript received 17 Jul 80, after revision 14 Nov 80) pp 867-869

KAN, V., Institute of Physics of the Atmosphere, USSR Academy of Sciences

[Abstract] The author discusses low-frequency (several cycles per second) flickering of stars observed from the "Salyut-6" orbital station and sets up a mathematical apparatus that makes it possible to evaluate the characteristic values of variations in the atmosphere's refractive index on the basis of the flickering index. Of the possible mechanisms causing such flickering, the author favors discoid formations that appear as the result of the collapse of internal waves and that have variable vertical density. Figure 1; references 8: 7 Russian, 1 Western. [5-11746]

DETERMINING SATELLITE ORBIT GIVEN LIMITED MEASUREMENT ERRORS

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 4, Jul-Aug 81
(manuscript received 24 Jun 80) pp 513-517

KOTYV, Ye. O.

[Abstract] The author formulates the problem of determining a set of evaluations of orbital vector components in such a manner that the error in each evaluation is minimal for the most unfavorable realization of the measurement errors for that evaluation. He then presents two solution methods: precise and approximate. The more accurate one involves the use of standard linear programming methods, but may be unsuitable because of the number of computations involved. The other is less accurate but does not require as many computations. The author concludes by proposing a computer algorithm for the solution of the problem. References 6: 4 Russian, 2 Western.
[7-11746]

UDC 629.7

SATELLITE OSCILLATIONS IN PLANE OF ELLIPTICAL ORBIT

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 5, Sep-Oct 81
(manuscript received 30 Apr 80) pp 674-679

ZEVIN, A.A.

[Abstract] Oscillations of a satellite in the plane of an elliptical orbit are described by the equation

$$(1 + e \cos v) \delta'' - 2e \sin v \delta' + \mu \sin \delta = 4e \sin v,$$

$$\delta' = \frac{d\delta}{dv}, \mu = \frac{3(A - C)}{B}, |\mu| \leq 3, 0 < e < 1 \quad (1)$$

where δ is the librated angle between one of the principal central axes of the ellipsoid of inertia of the satellite and the radius-vector of its center of mass; v is the true anomaly; A, B, C are the principal central moments of inertia; e is orbital eccentricity. From this point of departure the author makes a qualitative investigation of plane oscillations of a satellite in an elliptical orbit. It was possible to obtain the condition of uniqueness of 7 π -periodic solutions and find their bilateral evaluations. (In contrast to known analytical results based on the assumption of the smallness of $|\mu|$ or e the stability conditions obtained in this study are not asymptotic.) The conditions of stability of periodic oscillations of a satellite relative to the radius vector and the conditions of stability of rotations of the Mercury type are determined. Figures 1; references 9: 1 Russian, 8 Western.
[24-5214]

UDC 535.24:523.42

SPECTROPHOTOMETRIC EXPERIMENT WITH 'VENERA-11' AND 'VENERA-12' DESCENT
VEHICLES, PART 3: RESULTS OF PHOTOMETRIC MEASUREMENTS

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 4, Jul-Aug 81
(manuscript received 17 Apr 81) pp 599-612

MOROZ, V. I., GOLOVIN, Yu. M., MOSHKIN, B. Ye. and EKONOMOV, A. P.

[Abstract] The authors present the preliminary results of an investigation of the spatial distribution of scattered solar radiation in Venus's atmosphere, as determined from measurements made with the scanning photometer channel of the scanning spectrophotometers carried by the "Venera-11" and "Venera-12" descent vehicles. Measurements were made in four spectral bands that were separated by absorption filters. The authors describe the instrument setup in detail and present data on such parameters as the altitudinal dependences of the atmosphere's internal albedo and the difference flow, the dependence of the atmosphere's spherical albedo on wavelength, and the solar radiation heat influx at different altitudes on different spectral bands. Figures 15; references 20: 13 Russian, 7 Western.
[7-11746]

UDC 550.388:523.42

THREE-DIMENSIONAL SHAPE AND LOCATION OF SHOCK WAVE NEAR VENUS

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 4, Jul-Aug 81
(manuscript received 23 Mar 81) pp 613-623

SMIRNOV, V. N., VAYSBERG, O. L., ROMANOV, S. A., SLEYVIN, D. A., RASSEL, K.T. and INTRILIGEYTOR, D. SH.

[Abstract] The authors note that there is a discrepancy in the location of the shock wave front at Venus, as determined from data gathered by the Soviet "Venera-9" and "Venera-10" and the American "Pioneer-Venus" satellites. They present the two hypotheses that have been advanced to explain this discrepancy, then conduct a further analysis and comparison of the data for the

purpose of reconciling the differences. Among other things, they conclude that there is a morning-evening asymmetry in the shock wave, that it has a nonsymmetrical shape relative to the direction of arrival of the solar wind because of the effect of the interplanetary magnetic field, and that its axis is turned additionally through an average angle of about 70° toward the side of the increase in the aberrational effect. Figures 10; references 19:

6 Russian, 13 Western.

[7-11746]

UDC 551.510.53:523.42

MODEL OF ION COMPOSITION OF VENUSIAN DAYTIME IONOSPHERE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 5, Sep-Oct 81
(manuscript received 3 Nov 80) pp 733-748

IVAKOV, M. N., KRASITSKIY, O. P. and PAVLOV, A. V.

[Abstract] The authors have formulated a model of ion composition of the daytime Venusian ionosphere in the range of altitudes from 100 to 220 km, consisting of O_2^+ , CO_2^+ , O^+ , He^+ , H^+ , N^+ , CO^+ , C^+ , CO_2H^+ , NO^+ , N_2^+ and electrons and based on the most complete scheme of physicochemical processes. The results of computations of the concentrations of ions agree with the results of measurements with an accuracy not less than a factor of 2-3 at all altitudes (and at some altitudes coincide with them) for all ions at the terminator and O_2^+ , CO_2^+ , O^+ , He^+ , NO^+ ions at the subsolar point and by a factor of 3-4 for C^+ , N^+ , (CO^+ + N_2^+) at the subsolar point. At the main ionospheric maximum, situated at altitudes 139-146 km, $[e]$ varies in the range $(3-11) \cdot 10^5 \text{ cm}^{-3}$, increasing by a factor of approximately 2 with an increase in solar activity from the minimum to the maximum and its variations from the subsolar point to the terminator also consist of a factor of about 2. A study was made of the relative role of the 64 reactions included in the model. The observed content of H, H_2 , NO and C in the upper atmosphere was estimated. It is shown that H_2 exerts a decisive influence on the altitude of the upper maximum and the electron concentration in it through the rapid reaction $O^+ + H_2 \rightarrow H + OH^+$. Evidence is cited that excited particles make an appreciable contribution to the photochemistry of N^+ and N_2^+ near the subsolar point. Figures 5, tables 6; references 75: 18 Russian, 57 Western.

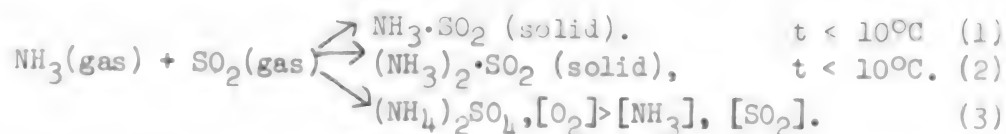
[74-0003]

NATURE OF SMALL AEROSOL PARTICLES IN UPPER PART OF VENUSIAN CLOUD LAYER

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 5, Sep-Oct 81
(manuscript received 6 May 81) pp 794-797

TITOV, D. V.

[Abstract] In the Venusian cloud layer, at least at altitudes ~60 km, there is absorption of radiation in the blue and near-UV parts of the spectrum ($\lambda = 0.3-0.5\mu\text{m}$). This is indicated, for example, by a strong decrease in spherical albedo of the planet in the mentioned wavelength range and also the results of experiments aboard the descent modules of the "Venera-11", "Venera-12" and "Pioneer-Venus." It is still unknown what substance is responsible for the absorption of UV radiation in the Venusian atmosphere. In this article it is suggested that the UV absorber is $\text{NH}_3 \cdot \text{SO}_2$ as a result of the reaction between NH_3 and SO_2 in the gas phase. The properties of the products of the reaction vary in dependence on the conditions under which it transpires. With $t < 10^\circ\text{C}$ there are two types of compounds which are stable: $\text{NH}_3 \cdot \text{SO}_2$ and $(\text{NH}_3)_2 \cdot \text{SO}_2$. The first is a yellow finely disperse aerosol, formed with an excess of SO_2 , whereas the second is a white aerosol which is formed with an excess of NH_3 . With a great abundance of oxygen the product is ammonium sulfate. The possible reactions were investigated under laboratory conditions. The following reactions are possible:



Not only these reactions lead to aerosol formation. The products of gaseous reactions between NH_3 and such minor atmospheric components as HCl , NO_2 and H_2O also are easily condensed with the formation of solid particles. Figures 2, tables 1; references 9: 3 Russian, 6 Western.
[24-5303]

SCATTERING OF ULTRAVIOLET RADIATION IN RESONANCE LINES HeI 584 Å AND OII 834 Å
IN VENUSIAN UPPER ATMOSPHERE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 5, Sep-Oct 81
(manuscript received 22 Jun 81) pp 797-799

MURGIN, M. S. and SHOLOKHOV, V. S.

[Abstract] During December 1978 Venus was reached by the two vehicles "Venera-11" and "Venera-12". One of the assigned missions was registry and measurement of the intensity of scattered UV radiation in the upper Venusian atmosphere in a joint Soviet-French experiment. The measurement data in the resonance lines with sighting of the illuminated disk can be interpreted only after solution of the transfer equation. Figures 1 and 2 in the text illustrate the intensity of emission in the HeI 584 Å and OII 834 Å lines. It is shown that there is a monotonic change in the intensity of emission for the HeI 584 Å line over the disk with a gradual increase from the dark limb, which lies very close to the nighttime terminator. It can be postulated that the HeI concentration over the level where the absorption of solar radiation by CO₂ molecules is predominant changes and with an increase in temperature there is an increase in the concentration of atomic helium. Near the bright limb there is a small increase in emission intensity registered by both vehicles. The best correspondence between the theoretical curve and experimental data was obtained with $\tau = 0.7$ (τ is optical thickness for scattering) in the case of the atomic helium line. In the case of ionized oxygen the best correspondence was obtained with $\tau = 0.4$. The concentrations of atomic helium $4.5 \cdot 10^5 \text{ cm}^{-3}$ at an altitude of 145 km and singly ionized oxygen $2.5 \cdot 10^4 \text{ cm}^{-3}$ at an altitude 250 km, obtained in this study, agree with measurements made by the "Pioneer-Venus" station. Figures 2, tables 1; references 8: 1 Russian, 1 Western.

[44-5303]

UDC 621.371

RADIO ENGINEERING METHODS FOR INVESTIGATING CIRCULATION OF PLANETARY ATMOSPHERES

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 4, Jul-Aug 81
(manuscript received 16 Feb 81) pp 574-590

ARCHANGEL'SKIY, V. A., KERZHANOVICH, V. V. and TRUSOV, B. P.

[Abstract] The authors describe measurements of the circulation of Venus's atmosphere made by the "Venera" stations and the "Pioneer-Venus" probes.

Three velocity components are measured: one ray and two tangential ones, with the latter being measured by differential interferometry with a superlong base line. The authors discuss each type of measurement in detail, as well as such factors as evaluating measurement accuracy and the accuracy of the determination of a probe's coordinates and the wind velocity. They then extend their conclusions to Jupiter and Saturn and note the differences between surveying these planets and surveying Venus. Figures 4; references 18: 12 Russian, 6 Western.
[7-11746]

UDC 524.31

SPACE AND GROUND SPECTROPHOTOMETRIC OBSERVATIONS OF GROUP OF CLASS F, G, AND K STARS

Yerevan ASTROFIZIKA in Russian Vol 17, No 3, Aug 81
(manuscript received 23 Sep 80) pp 495-508

YEPREMYAN, R. A., Byurakansk Astrophysical Observatory

[Abstract] Results are presented from measurements of a group of 22 class F, G, and K stars in the area of Capella within the wavelength range 2,400A to 4,800A. Material in the UV range (2,400A to 3,800A) was obtained in 1973 from the Orion-2 satellite, and in the long-wave range (3,500A to 4,800A) from ground observations made in 1976 using the 70-cm meniscus-lens telescope at the Abastumansk Observatory in combination with an 8° prism. The luminosity of most of the stars studied was previously unknown and they were assigned a classification in accordance with the criteria used at the Abastumansk Observatory; details are provided in a table. With one exception all stars were less than 300 parsecs distant; 11 stars were assigned to class F, 6 to class G and the rest to class K. Findings were in good agreement with the Kurucz theoretical model for stellar photospheres; in cases of double stars there was some divergence between theory and observation. It is concluded that combined ground and space observations could become a powerful means both of revealing the invisible low-temperature component in low-luminosity double systems and in establishing the presence of middle or late class giants or supergiants as one of the components in unresolved double systems, which was the case for four of the systems studied here. Figures 6; references 12: 2 Russian, 10 Western.
[34-9642]

LIFE SCIENCES

PSYCHOLOGICAL ASPECTS OF AEROSPACE ORIENTATION

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 10, Oct 81 pp 34-35

[Article by Lt Gen Avn G. Beregovoy, twice Hero of the Soviet Union, honored USSR test pilot, USSR pilot and cosmonaut, candidate of psychological sciences: "Orientation in the Air and in Space"]

[Text] The practical experience of instruction and training of cosmonauts on the ground and analysis of their activities during space flight provide convincing evidence that control accuracy and precision in the making and execution of decisions by spacecraft commanders, especially in non-programmed situations, depend to a great extent on their experience as pilots. Without a doubt, piloting a space vehicle has features peculiar to it alone. Nonetheless, the differences between space flight and the flight of an aircraft in the atmosphere seem fundamental only at first glance. In fact they have quite a lot in common--primarily as related to spatial orientation in the atmosphere and in space.

Readers of aviation literature manifest an interest in analyzing instances of loss of attitude and the appearance of illusions, and in the theoretical basis for these. This is not a casual interest, since the procedures for training pilots and cosmonauts and their reaction to information received from attitude instrumentation depend to a great degree on accepted theory. This is a pressing issue for both aviation and cosmonautics, whose future is related not only to interplanetary flights, but to spacecraft landings on the earth as well. Only well trained pilots are capable of executing such landings.

One of the major components of any flight program is man's spatial orientation, i.e., the ability to determine his own position relative to the force-of-gravity vector, and to perceive objectively the form and size of objects, their position relative to one another and to himself.

Man perceives spatial entities chiefly thanks to the functioning of visual, static-kinetic and muscle-joint analyzers. It is well known in this regard that orientation on the ground does not require a great expenditure of mental energy, and comes about practically subconsciously. Man's orientation in flight changes substantially, especially when he is unable to view natural reference points. This is because the basic foundation of his orientation is transformed; its fulcrum is changed. Both on an aircraft and aboard a space vehicle, man enters the so-called connected system of coordinates. Scientific literature has described sufficiently well all the physiological mechanisms for the functional reorientation of

man's analyzers while under the influence of weightlessness. We will therefore examine only the psychological aspect of the question.

At first glance such concepts as "up" and "down" would seem to play no significant role in a condition of weightlessness. Training experience in mock-up spacecraft, however, has shown that man still rigidly ties himself right away to the same visual horizontals and verticals of his instrument panel and equipment that correspond to the body scheme to which he is accustomed--up, down, front, back, left, right. In other words, the principle--my position exists as related to another object--becomes reinforced. Observations of the cosmonauts show that they try to stick to their earth habits--head up, feet down. Arrangement of the whole interior with a "floor-ceiling" emphasis helps to overcome vestibular discomfort. Such orientation is closely related to the process of controlling a space vehicle. Soviet scientists have established that spatial orientation is an independent activity, an integral part of piloting that is always aimed at achieving a definite goal--maintaining the assigned course, executing a landing on an airstrip, controlling an aerospace vehicle, etc. This goal is achieved through maneuvering based on spatial perception--I, together with the airplane, am moving either towards an object or away from it.

There exist a variety of means for instrumental presentation of the target area as a physical point in space. From the position of the individual who is piloting the aerospace vehicle, it is always better to travel to the target rather than "drive" it towards oneself. This is apparently related to particular biological-development features of the organs of equilibrium and spatial orientation. In fact, man always moves and orients himself among objects. If they in turn begin to move around him, there may occur dizziness, nausea, etc. It happens that student pilots on their first flights perceive their motion as rotation of the earth around the airplane. This can be a cause of strain for them in the air. Gradually the horizon becomes stationary, and they feel a complete sense of personal movement together with the airplane. Attitude is determined as related to the stationary horizon.

I might boldly assert that this system of perception is quite solid. I will cite an example. After a lengthy break from flying, I had to fly a Yak-40 at night and execute a descent for landing using a laser system. While getting familiar with it prior to the flight, I noticed that the configuration of laser beams in space would change depending on the airplane's descent trajectory. The question arose--how would the readings from this system match up with readings from the remote-indicating gyro horizon (RGH) in actual flight? It was nice to see and to realize that the system allowed me to accurately determine the aircraft's movement, and execute maneuvers in an environment where the idea of position to which I was accustomed coincided with that shown by the laser beams and RGH readings. I believe it worked out this way because the laser-beam system was rigidly earth-oriented.

There are two concepts of flight visualization using a gyro horizon--the view of a moving airplane flown by a pilot relative to a stationary earth and horizon (the principle of the RGH-type gyro horizon), and the view from the airplane of a moving earth and horizon (the IGH-type gyro horizon). In the second case, the pilot "flies" the earth or horizon; the aircraft itself is considered stationary. The unnatural quality of such a perception is especially acutely felt when you enter the clouds after a visual flight and the IGH instrumentation shows rotation of the horizon line. You get the desire to stop the rotation and steer in the opposite direction.

Test pilots have conducted an interesting experiment using a windshield indicator that shows information from the direction of view and focused to infinity. Here the horizon line moves. In executing visual flight maneuvers, pilots experienced no difficulties and didn't even realize that the horizon line was changing on the indicator to coincide with the natural horizon. But as soon as the pilot began his maneuver to enter the clouds, he felt movement of the aircraft in a direction opposite to what he had steered. In this instance, without being able to view natural orientation points, the individual himself became the reference point and space "moved" around him.

But is this so unnatural? Pilots from other countries fly airplanes using gyro horizon where the horizon line is movable. In all fairness, however, it must be noted that most of the scientific research conducted by American, German and British engineering psychologists have shown the advantage of the attitude indication adopted in our country. Engineering psychology must be used to aid in understanding and evaluating the practical significance of such results--dealing with the problem of matching man's psychological qualities with the technical characteristics of the machines he is controlling. Most important in resolving this issue is the mental image of the controlling process which assists man in regulating his activities.

It should be specially emphasized that reflection of reality in psychology is not passive--it is constantly changing. For example, once we have become acquainted with an object, we always recognize it and correctly judge its size, form, etc, regardless of how it is positioned with respect to our eye. In other words, its form stays in our memory--we retain a definite knowledge and judgment of it. Memory, however, does not function as surely and precisely as a system of analyzers, which achieves orientation based on the constantly acting force of gravity.

Unfortunately, orientation in flight based on the earth's gravitational force is difficult, insofar as the linear and angular acceleration of an aircraft actively affect the vehicle compartment, the static-kinetic and sensory analyzers, and cause the appearance of illusory sensations. The pilot is trained to overcome the illusion using two means--instrument readings and image of flight. The latter depends on the pilot's experience and is the result of overcoming outside-world distortions associated with movement of the aerospace vehicle. This mental skill, developed over the course of an entire life of flying, enables a pilot to correctly evaluate the attitude of an aircraft, and perceive ground and horizon as something constant, stationary.

Insofar as mental image is the active reflection of the world as viewed, the earth and visible horizon do not rotate around the airplane for an experienced pilot--they are stationary and always below. As a result of flying experience, visual signals that distort the visible world are transformed into a non-distorted world where the horizon is stationary, with the help of psychological regulation. Only the airplane moves, swerves and turns. Knowing this, the pilot effects correct orientation in space and controls the vehicle. Correspondingly, instrument indications should help the pilot fly the airplane, and not the horizon.

It should be stated, however, that advocates of the moving-horizon indication--using the so-called common sense hypothesis--consider this approach more acceptable to the pilot. But what comprises this common sense? According to these experts it is

chiefly the fact that the indication with stationary airplane silhouette and movable horizon creates an illusion of a visible world, and is therefore more natural. To confirm this they present pictures of upside-down flight where, in their opinion, the pilot flying the aerospace vehicle using a moving-silhouette indicator must feel a strange and adverse sensation--the wheels and sky are up above, while in visual flight he sees the earth overhead.

But is this so? Although a pilot flying upside-down sees the earth above his head, when he enters the clouds he knows full well that it is below. Mental image of flight guides his actions. It transforms a "false world" into a true situation. The question arises--is there any sense in presenting information on the gyro horizon so as to be constantly transforming it into a form adequate to the task? In all probability this is not logical.

Flying is essentially possible using any gyro horizon you may choose. An individual will get accustomed to anything. But we have no right to reason this way. There might be a day when inherent reflex is stronger than one's habit--and then an incident in flight is inevitable. The most important thing is that the cost of piloting, i.e., the expenditures in mental and physical strength to get the highest airplane-flying quality should be minimal. The basic concept of flight safety in adverse weather conditions is inferred here.

A great deal of experimental research has been conducted in this country and abroad where the two types of roll indication were compared with respect to many features, including number of erroneous actions per unit time for an aircraft trying to extricate itself from an adverse situation, piloting quality, time required to shift from one roll position to another, and others. Results of the research and the subjective opinion of pilots as well provide convincing confirmation as to the advantage of an indication using a moving aircraft silhouette. Advocates of the moving-horizon indication were also found who were able to adapt more easily to these instruments. There turned out to be considerably fewer of them, however, than the number of moving-silhouette advocates.

Conclusions can be drawn. Image of flight is the basis of a pilot's activity when flying an airplane. In maneuvering, he does not match up what he sees to the outside world, but orients himself on the presentation of an airplane in motion relative to a stationary earth. His image of flight is developed subconsciously for visual flight--based on his piloting experience; for instrument flight the pilot must expend a certain amount of mental effort in order to create a flight image that corresponds to the airplane's attitude, and the gyro horizon must assist him in this.

We feel that there is no special need to show that flying a moving silhouette is relatively easy, since, mnemonically, it corresponds to movement of the controls for altimeter, rate-of-climb and speedometer guidance. Nonetheless, we cannot understand where the terminology "view of airplane from the earth" came from, since this does not reflect the essence of orientation. The pilot sits in the airplane, but is mentally in a silhouette on the gyro horizon. This is why a pilot flying upside-down quickly understands what direction he should steer in coming out of a roll. In my own day I had occasion as a test pilot to test many sighting systems, built on a variety of principles of aircraft attitude representation and target marking. I became convinced that you feel far more sure of yourself using the kind of system

where it is the airplane that swerves, and not the horizon. If the target is on the right, then you know you don't have to use left roll.

All that has been said concerns instrument flight--because in visual flight, either the horizon or the target provides perfect orientation. It cannot be ruled out that the development of technology and engineering will enable us to create flight visualizers which, even during instrument flight, will permit viewing an actual horizon, and will do away with relearning difficulties and problems in forming a multi-component image of flight.

As far as space flight is concerned, there are still many questions today that require further research. It would be technologically advisable to build systems for presenting information while at the same time meeting flight requirements in space and in the atmosphere. A certain amount of compromise is not ruled out, of course. From the point of view of the human factor, however, it must be to man's benefit, especially in the most responsible areas of flying--where the cosmonaut directly controls the space vehicle. The reliability guarantee for the entire "cosmonaut - ship" system is determined primarily by the activity of man kept intact, by the use of his innate and acquired reactions, and of the psycho-physiological conformity of his conduct, habits and skills. The individual's consciousness must be utilized according to a prescription of realizing and reflecting the essence of a flight situation, of choosing the means to achieve the aims of the operation--and not one of constantly transforming information into a form convenient for understanding. Research conducted by aviation psychologists to bring to light a system of psychological regulation in piloting and orienting in aerospace will, without a doubt, provide great assistance to cosmonautics as it is accomplishing its tasks.

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SPACE ENGINEERING

DOCKING METHODS FOR SPACECRAFT IN ORBIT

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 5, May 81 pp 42-43

[Article by V. Syromyatnikov, Lenin Prize laureate, doctor of technical sciences: "Docking in Orbit"]

[Text] At the reader's request: "Tell us please about the docking assemblies used for the 'Salyut-6' space station and the 'Soyuz' spacecraft. How is the design of our docking systems different from those of other countries? What is the outlook for the development of docking systems in outer space?" The officers A. Lukachev and V. Ganzhayev presented our editors with this request. V. Syromyatnikov, Lenin Prize laureate and doctor of technical sciences, is a leading expert on docking procedures in space and offers the following response to the readers' questions.

The word "stykovka" [joining, mating, docking] encompasses a great deal and has many meanings. It can apply to pipeline, ducting, electrical connections, and individual parts of construction, to include the stages of a rocket. Finally, the word can apply to spacecraft modules. Is there any difference between accomplishment of the mating process in outer space and on the earth?

In order to answer this question we will take a look at a shop where the final phase in mating two spacecraft modules is taking place. Fitters of the highest caliber are preparing the surfaces of the docking rings to be joined and their rubber seal, literally blowing little specks of dust off of them. The upper module, rocking slightly on its suspension, is lowered in such a way as to allow the guide studs to enter the receiving apertures. The fitters then fasten the flanges with bolts, while observing a predetermined sequence and a particular tightening torque. The threaded connections are secured with great care, since the launch vehicle will be subjected to intense vibrations during flight. Only under such conditions will the junction remain intact, rigid and hermetically sealed.

In the next phase, the fitters set about making the electrical, pneumatic and hydraulic connections. They exercise great care in fitting and testing every connection. It takes many operational shifts to complete assembly of the modules and the subsequent check of the junction's hermetic seal, along with electrical and hydraulic testing.

Matters are different in space, where the junctions and all their elements must be completed automatically, in the course of several minutes, without any preliminary examination or preparation of the seal and docking ring surfaces. Like any bodies in space, spacecraft have six degrees of freedom, i.e., they can move in any direction and rotate about any axis. Rendezvous is therefore accomplished with the help of a complex, six-channel guidance system. Controlling all coordinates simultaneously, this system attempts to maintain the aligned position of the space vehicles. But, as is generally known, in order to effect such guidance it is necessary to constantly track the relative position of the vehicles accomplishing rendezvous.

The multi-channel radar system "Igla" [needle] is used for automatic rendezvous between the spaceships "Soyuz" and "Progress" and the "Salyut" orbital station. It measures relative deviations from the aligned position as well as the rate of change of these coordinates. The guidance system of the ship playing the active role processes the radar signals and cuts on guidance thrusters so as to minimize deviation and speed with respect to all coordinates (with the exception of approach rate along the longitudinal axis). Generally speaking, the orbital station doesn't stand in place either. It is controlled so as to maintain the mutual orientation and stabilization in space. As a result, the station usually rocks slightly with respect to its alignment position, or rotates slowly--drifts, as they say.

The Soyuz spacecraft are equipped with a fully automatic rendezvous system. If necessary, however, the cosmonauts may control the spacecraft themselves. When the cosmonaut is exercising manual control of the rendezvous operation, he is performing two basic functions. In the first place, he evaluates the attitude deviation of the ship using spatial targets or a system of luminescent indicators, which will provide immediate error determination with respect to all coordinates. Secondly, using two position controls, he regulates the small rocket thrusters that provide the necessary forces and torques.

It is not easy to enter the "narrow gate" when it floats upwards, then swings in various other directions. As a result, relative displacements accumulate which can amount to hundreds of millimeters and dozens of degrees. Thus, the first substantive feature of space vehicle docking is their mating under initial conditions of significant displacement and distortion.

All of the basic mating operations are accomplished by the docking assembly. It is termed an active component and usually mounted on the spaceship. It

consists of a casing with docking ring and the docking mechanism. The latter must precisely join, and then engage the assemblies under conditions of significant initial displacement. Then the spaceship and station must be aligned and the docking rings brought into contact. This must be accomplished in such a way that the guide studs (pins) enter the receiving apertures (sockets). The docking mechanism must not only engage, but must compensate for displacement with respect to all coordinates.

The basis of the Soyuz spacecraft's docking mechanism is the docking rod which enters the receiving cone on the space station. The cross-section diameter of the cone is based on the maximum allowable error for executing rendezvous. Engagement--initial contact, as it is called--occurs when the tip of the rod, generally after several hits against the side surface of the cone, enters the socket located at its apex. Engagement is accomplished by means of several latches on the tip (similar to latches on ancient locks).

When the cone receives the hits, and when the tip subsequently enters the socket, the docking rod plays the role of a complex buffer--the movable element of a shock attenuation system. The tip can displace in both the longitudinal direction due to rod settlement (as in the case of the usual buffer) and additionally in the transverse directions. Following engagement, the spacecraft and the station form a common point-joint relative to which angular oscillation of the vehicles takes place. The docking mechanism limits the oscillations, and the attenuation system absorbs the energy, dampens and suppresses these oscillations.

Finally, having completed their oscillations relative to one another, the modules of the space complex-to-be settle down. The basic dynamic processes have ended. The next step is alignment and constriction up to the point of contact between the docking rings. This function is accomplished by the docking mechanism, which draws in the rod with the help of an electric drive that not only moves the rod, but turns on a lever mechanism as well. The levers are positioned, and, interacting with the receiving cone, they align the vehicles relative to the transverse axes, i.e., with respect to pitch and yaw. Roll alignment takes place at the same time, due to constriction of the head latches in the tapered grooves of the socket in the receiving cone. In the event the latches slip along the lateral faces of the grooves, a rotational moment is created with respect to roll (rollers are mounted on the ends of the levers with the aim of reducing friction against the cone). The first phase of docking is accomplished in this manner for construction designs having the so-called "shock-attenuation" initial contact. Docking mechanisms for the Soyuz spacecraft fall into this category.

It is characteristic that guidance systems are cut off at the instant of initial contact, the space vehicles move by inertia, and the process is usually accompanied by several intense impacts. This is the most dynamic, the most strained moment in the docking operation. It evokes apprehension and some experts have doubts as to the correctness of such a design.

Proposals on ways to avoid the danger of collision are often aired. Those most often heard advocate the use of an intermediate, flexible link between vehicles--a kind of lasso or harpoon ejected from the active ship. Such an approach has been analyzed not only by private inventors. For example, when setting about designing the docking apparatus for the Apollo lunar program, U. S. experts examined, and even conducted experiments with several design varieties of long and rather flexible linkages which moved in and out of the command module prior to engagement with their mating components in the lunar module. One of the variants even envisages the possibility of manually controlling the flexible link by rocking it from the spaceship module. But the problem is that a flexible initial link is unable to limit or control the relative movement of the vehicles, or to attenuate the energy of such movement. The process is by no means simplified by this approach, and additional disturbances and interference arise--the fact is it is necessary to hold the flexible link taut, even if gently so. In order to counter these disturbances it is necessary to expend fuel, an expensive commodity in outer space. At the same time, collision of parts not so designed cannot be ruled out. This is why U. S. experts, as long ago as 1963, abandoned flexible links, and the docking mechanism for the Apollo spaceship used for docking with the lunar module, and later with the Skylab orbital station, utilized attenuation linkage.

Without a doubt, guidance systems for space vehicles will be perfected. It cannot be ruled out that precision measurement and guidance facilities will appear, capable of solving practically any and every task. But in all likelihood, there will not be any need for flexible linkage in docking. Perhaps the requirement for the docking mechanism itself will fall away--vehicles will rendezvous with sufficient accuracy and at such low speeds that direct link-up between guide pins and sockets on the docking rings will become possible.

In the meantime, it must be decided how best to effect rendezvous today--slowly or swiftly? Prior to docking, space vehicles conduct their approach at a speed of several dozen centimeters per second. Automatic systems, or those using manual guidance, attempt to sustain a speed somewhere in the middle of the allowable range. Which is more dangerous--low or high approach speeds? It turns out that both are poor. In the former instance, there may not be sufficient kinetic energy for the vehicles to make the rod tip reach the docking ring socket and operate the latches. If there is no engagement, the vehicles will begin to "fall to pieces" (in which case rapid vehicle separation is envisaged). In order to facilitate the engagement process at low speeds, small rocket thrusters on the active ship are used, and thrust is directed "forward." They cut in upon initial contact of the rod tip against the ring, and press the rod into the socket. As for high-speed rendezvous, there may not be sufficient power capacity for shock attenuation and the resulting impact forces may arise.

Some attention should be devoted to the shock attenuators for docking mechanisms. On the Apollo spaceship, and even earlier, during completion of the Gemini project, American designers used air and hydraulic shock attenuators similar to those used in automobile suspensions or airplane landing gear. Similar equipment was used later by the Americans in new, androgynous assemblies built for the "Apollo-Soyuz" project. Electro-mechanical dampers are used for docking mechanisms in the Soyuz spacecraft. Which is best--electro-mechanics or hydraulics?

The basis for Soviet shock attenuators is the electromagnetic quick-response brake (EQB). When the vehicles collide, the brake rotors can speed up to levels of tens of thousands of revolutions per minute within thousandths of a second. That's the degree of its response. To decrease the inertial loads, all moving elements are reduced in weight to the maximum possible degree. Thus, the brake rotor is constructed in the form of a hollow sleeve made of pure aluminum, and positioned in the clearance area between two ring magnets made of magnetic-hardened materials. Within the 5-10 watt limits of an electric motor braking at maximum speed, the EQB has a peak power capacity of over one kilowatt.

There is one additional significant element in energy absorption--the self-adjusting friction brake, whose automatic control mechanism provides for a strictly-regulated force of shock attenuation.

Certain elements often dictate the choice of design for the mechanism as a whole. The purely electro-mechanical docking mechanisms of the Soyuz spacecraft are constructed according to the so-called combination design--the basic energy-absorption element of the longitudinal shock attenuator, the self-adjusting friction brake, is combined with the safety coupling of the power drive. This is the most efficient design. Upon constriction, for example, it is not necessary for the drive to compress the longitudinal shock attenuator. In the docking mechanisms for the Gemini and Apollo spaceships, the power drives and shock attenuators are positioned in parallel fashion. Upon constriction, force of the power drive is partially spent on compression of the shock attenuators. Advantages and disadvantages of the combination and parallel designs became particularly manifest when the ADPA's (androgynous peripheral docking assemblies) were developed in conjunction with the Apollo-Soyuz program. It is no accident that, having completed work on ADPA, NASA experts signed a contract with a firm for building an electro-mechanical variant.

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BAYKONUR LAUNCH COMPLEX

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 10, Oct 81 pp 42-44

[Article by Engineer Colonel V. Gor'kov, candidate of technical sciences, special correspondent for AVIATSIYA I KOSMONAVTIKA: "Baykonur: Yesterday and Today"]

[Excerpt] Even at a considerable distance from the launch complex you can see the rocket booster illuminated by floodlights. It stands like a tall building dressed in floors of maintenance platforms. The service tower has changed it thus. Rays from the floodlights are jumping incessantly from one tower platform to another, as if tracing out a timetable of the technical launch-preparation cycle.

The clock has just struck midnight. A new day has begun--10 Dec 1977. Here on a little piece of Kazakhstan land, work is in full swing. Final operations are taking place to prepare the "Soyuz-26" space vehicle for launch. The fueling operation for the rocket booster is being completed.

A bus speeds along the steppe, lighting up the asphalt highway with its powerful headlights--Yu. Romanenko and G. Grechko are travelling to the test and assembly building. Here, after putting on their space suits, they will receive brief, final instructions from prominent experts--literally only a few minutes. Then back to the bus. At exactly the appointed time the bus will head for the launch pad. The cosmonauts will report to the chairman of the State Commission; then a quick good-bye and they go up to the spacecraft compartment for the trip to meet with "Salyut-6."

The people of Baykonur were heading for work at the time "Soyuz-26" went into orbit. For many city dwellers they were hurrying along, pressed for time. Some were headed for the satovoz (that's what the local train system is called), others for cars and buses. Their journey led to the cosmodrome sites from which manned and unmanned space vehicles leave regularly for parts of the universe. On 29 Sep 1977, "Salyut-6" itself was launched from here.

It will take the path to the technical site of the "Soyuz" complex. Its basic structure is the test and assembly building. The height of this building does not exceed that of a five-story house; its length is over a hundred meters. Inside are two giant cranes and several sets of railway track. The center track receives the rocket booster stages and the space vehicle, and subsequently takes them out to the launch pad. The other tracks are used for moving assembly-docking carts where rocket booster stages are stowed for checks and testing.

Instrument technicians and electricians work here--as do chemists, radio technicians, mechanics and other specialists. At first they will conduct all the programmed operations with "dry" objects, using transferred and stationary equipment for a full cycle of checks and testing for all systems and assemblies. Then they will send the space vehicle by rail to the fueling station, where it will receive the required load of fuel and compressed gases.

The fueled spacecraft returns to the test and assembly building where the rocket booster is already assembled on a junctioning jig. The propulsion device for the emergency escape system is joined to the space vehicle, then the vehicle itself to the rocket booster. A powerful girder crane places them on a mounting rig bound for the launch area. Passing through a little area of steppe, it draws near the launch complex.

The basic component of the launch structure is a square, reinforced-concrete launch pad. Supported on three sides by powerful columns, it looks like a platform from which it would seem the rocket booster must push off prior to flying out into space. This impression grows stronger when the "tail" of the rocket booster is lowered into the aperture built at the structure's edge. Below, under the launch pad, a vast gas-escape channel stretches like an abyss. Beginning at the channeled gas deflector built under the rocket booster nozzles, like a dam it subdues and redirects the powerful current of flame disgorged by the rocket booster engines during launch. The base is mounted on the launch pad concentrically with the aperture. Four hinged support towers are attached to it, as are cable and fueling masts and a service tower.

Several meters from the launch system, a train stops with the mounting rig. Then a precision guide-in mechanism brings the rig in close to the aperture. The mounting rig is rigidly fastened to the base. Then the end of the rise beam floats upward, carrying the rocket booster with spacecraft to the launch system. In a few minutes it is standing vertically in the aperture of the launch structure. Lift mechanisms for the support towers are turned on. Their movement is strictly synchronized by tracking systems, and all four simultaneously approach positions for fastening the strap-on "summits," and locking the power belt. The mounting rig beam is lowered and the rig departs for the test and assembly building.

The rocket booster was hanging up on four powerful supports. Suspended only by the power belt of the support towers, it was subject to swinging and swaying in the wind like a pendulum. In order to avoid this, its "tail" is fastened at four points. Later, the stabilization system at the launch structure is turned on--this adjusts the almost thousand-ton structure into position, to an accuracy of a few angular seconds, and maintains it in a rigidly vertical position.

The service tower and compartment and the cable and fueling masts are brought up to the rocket booster. The fueling system hoses are raised along with the pneumatic gas-service line connectors, and the plugs and receptacles for the cable circuitry.

Beyond the slope of the gas-venting channel is the control bunker. This is a deep space which houses the control consoles for all systems in the complex. Transmission and execution of commands is registered here sequentially. There are also television monitors and a periscope in the bunker, allowing for view of telemetric information

is to how rocket booster and spacecraft preparation is progressing, in addition to monitoring the complex as a whole. The individual who effects launch conducts final pre-launch operations. Turning the launch key to "start," he activates the automatic mechanism for cutting on the rocket booster's engine systems. From this moment forward he receives all information at his console.

The fueling and cable masts recede. After another few seconds the powerful rocket booster engines carry the ship up into orbit.

If one is observing a night launch from an airplane, the impression is unusual. At the moment when--from the launch complex observation point--the engine flame from the third stage turns into a hardly-noticeable, glimmering point, the picture presented in the air is quite different. This point is gradually beginning to grow. Its color changes from violet to red. The rays of the morning sun so transform it, as the rocket booster heads that way.

The launch complex has become empty. The people who service the spacecraft launch are departing for the city. What kind of a city is this--whose name is linked with dates to be remembered in the conquest of space? There is a beautiful park here with attractions, a sports palace with swimming pool, a stadium covered over with green turf specially brought in, basketball and volleyball courts, a Palace of Culture, movie theaters, libraries with spacious reading halls.

There is a beach down by the river. There is a local "Matsesta," a mineral spring that attracts people all times of the year with its warm, hydrogen-sulfur water. On their summer days off the people here rest and relax in the bosom of nature. They head out for secluded little spots in launches, boats and cars. Those who love to fish go further out--to the lakes.

It is a young city, and, like any young city, there are many children and young people here. Nurseries, gardens, schools, a technical school and institute have been built for them. One of the most beautiful buildings is the "Palace of Pioneers and Schoolchildren."

The training complex for the cosmonauts--or "Cosmonaut" hotel, as it is known here--occupies a special position. This is perhaps the greenest little corner of the city. Here has been built here that a crew might need in the pre-launch and post-launch days--classrooms, a sports center, a complex for studying the cosmonauts' condition of health and observing their preparation and training for flight and during the readjustment period, a movie hall, a library. Analyzing and systematizing training and launch results, workers at the cosmodrome submit recommendations as to perfecting space-rocket equipment.

More than years have passed since the launch of the first artificial earth satellite, and the first launch site on our planet continues to write its chronicle. With the beginning of the fifth basic expedition--V. Kovalenok and V. Savinykh--to earth, the cosmodrome attended manned space flight by Soviet cosmonauts was accomplished by the scientific research complex "Salyut-6" - "Soyuz", in addition to flights of international crews taking part in the "Interkosmos" program. These flights are now part of history. And that same launch site from which the first artificial earth satellite and the "Vostok" spacecraft were launched entered to its credit yet another triumph--"first place," with its launch of the international crews on the cosmonaut ship.

"Relations between states have been called international since olden days," stated Comrade L. I. Brezhnev from the rostrum of the 26th CPSU Congress. "But only in our time--in the time of socialism--have they truly become relations among peoples. Millions and millions of people participate directly in such relations. This, comrades, is the principal achievement of socialism, its great merit to mankind."

"The field of our cooperation encompasses newer and newer spheres. An example of this is the "Intercosmos" program. Cosmonauts of the fraternal countries are working not only for science and the national economy. They are fulfilling a political mission of enormous significance as well."

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OPERATING PRINCIPLES OF OPTICO-ELECTRONIC INSTRUMENTS

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 11, Nov 81 pp 22-23

[Article by Colonel V. Fedorov]

[Text] The term optico-electronic customarily refers to instruments in which processing of information on the subject under observation entails conversion of radiant energy to electrical energy. Such instruments are often components of sighting and navigation systems and are intended for detection and recognition of visible terrestrial features and for measurement of their coordinates during the day under normal weather conditions and when haze is present.

Whether or not features with different colors and contrast levels can be detected and recognized depends on the observation conditions, the resolving power and sensitivity of the eye, and the properties of the optico-electronic instrument that govern its basic parameters.

Atmospheric conditions have a considerable influence on the transmission of electromagnetic waves. In a clear atmosphere or in haze, short infrared waves ($0.76\text{--}1.5\text{ }\mu\text{m}$) in the $0.95\text{--}1.05$ and $1.2\text{--}1.7\text{ }\mu\text{m}$ regions are transmitted better than waves falling into the visible region of the spectrum ($0.4\text{--}0.76\text{ }\mu\text{m}$). As a consequence, the distance from which objects can be detected with the aid of optico-electronic instruments operating in the region of short infrared wavelengths should be somewhat greater than that from which they can be discerned with the naked eye.

Perception of the ground surface is a function of its radiative and reflective properties. Reflective radiation is determined by solar radiation and exceeds intrinsic radiation for $\lambda < 4\text{ }\mu\text{m}$. The maximum of the solar radiation reaching the ground is virtually identical to the eye's spectral-sensitivity maximum. The reflection factors of most forms of ground cover are relatively constant in the visible region but can vary significantly in the infrared region.

Almost all types of natural cover can be divided into several groups with respect to reflectivity on moving through the spectrum. The first group comprises cover types whose reflection factors remain almost constant with varying wavelength (Fig. 1a). The second group consists of cover types whose reflection factors change somewhat with increasing wavelength (Fig. 1b). The third group comprises various sorts of green plant cover. The reflection factor for this group is more or less constant over the range $0.4\text{--}0.5\text{ }\mu\text{m}$, has a slight maximum at a wavelength of $0.56\text{ }\mu\text{m}$ and a

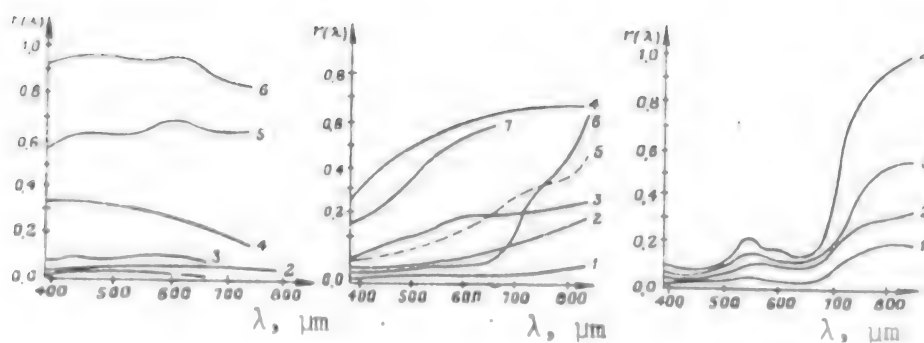


Figure 1. a: 1) Wet chernozem; 2) damp clay loam; 3) gray granite boulders; 4) ice; 5) melting snow; 6) fresh snow; b: 1-4) average curves for similar features (after Ye.L. Krinov); 5) wet forest; 6) dry steppe; 7) dry clay; c: 1) conifer forest in winter; 2) the same in summer; 3) deciduous forest in summer; 4) fresh green meadow.

pronounced minimum near $0.65 \mu\text{m}$ and rises rapidly with increasing wavelength, especially in the infrared region of the spectrum (Fig. 1c).

Image contrast is determined by the properties of the eye and the optico-electronic instrument, the reflection factors of the feature under observations and the ground cover, and the natural illumination, which depends on the time of year, hour of day, and type of cloud cover. The relative-spectral-sensitivity maximum of the eye lies at $0.555 \mu\text{m}$, while that of optico-electronic converters operating in the near short-wave infrared region is located at about $0.8 \mu\text{m}$.

The reflection factor of an object depends on the material from which it is fabricated, its shape, and the finish of its surface or external covering. The reflectivity of an object is also determined by the position of the sun relative to it and to the observer.

As can be seen from Fig. 1, the reflection factors at $0.555 \mu\text{m}$ and $0.8 \mu\text{m}$ differ considerably for such types of ground cover as ice, dry steppes, and especially green plants. As a result, features observable with optico-electronic instruments have totally different contrast with respect to the background (even negative in some cases) than when observed visually. Moreover, a section of a given locality is imaged on the instrument screen in different tones of a single hue (ranging from black to white), so that features are distinguished on the basis of shape and the relative arrangement of their elements. The image on the screen of an optico-electronic instrument thus differs in color and contrast from that to which the eye is accustomed. This undoubtedly creates definite difficulties in identifying features with the aid of optico-electronic instruments. The graphs in Fig. 1 can aid pilots and navigators.

in analyzing the properties of the ground cover and various features in order that the images that will be obtained under different natural illumination conditions can be predicted.

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COOPERATIVE EFFORT URGED FOR DEVELOPMENT OF ORBITAL POWER STATIONS

Moscow SOTSIALISTICHESKAYA INDUSTRIYA in Russian 22 Oct 81 p 4

[Article by R. Akhmetov: "Energy From Orbit"]

[Text] The generation of electric power on space solar-power stations and its transmission to earth on a microwave beam is now being studied by many experts as one of the practicable methods for solving power-engineering problems. The very idea of supplying the earth with electric power with the help of such stations was first stated by K. E. Tsiolkovskiy. "Rocket devices," he wrote, "will win unlimited space for people and will provide solar power two billion times greater than the power mankind has on earth." For this reason, the prospects for space solar-power engineering were examined at the 16th Lecture Series which took place in Kaluga and which was devoted to the development of the scientific legacy of the founder of theoretical cosmonautics. Here is what was said in this connection by Doctor of Technical Sciences and Professor of the Moscow Higher Technical School imeni N. E. Bauman S. Grishin, head of the section "K. Tsiolkovskiy and the Problems of the Space Industry."

In the 21st century, new constellations--the earth's power satellites--will begin to shine in the night sky. My belief in this is based primarily on the high rate of development of space science and technology. In only a little over two decades our country has come a tremendously long way from the launching of the first artificial earth satellite to the creation of unique complexes of the Salyut and Soyuz-type in orbit. Their appearance also offers the possibility of building large-scale installations in space and provides practicable outlines for designs which up until recently seemed fantastic.

On the other hand, I must mention that space solar-power engineering is ecologically the cleanest form of power production. Moreover, it is practically inexhaustible. Considering the atomic power industry, solar power-engineering can supplement it substantially. The sun sends to the earth in a single minute approximately as much energy as all the power stations in our country generate in a year and a half. There is even more energy in space, for there is no sunset, sunrise nor atmosphere of clouds obstructing the passage of the sun's rays. For this reason, each unit of surface area in space receives 10 times the solar energy that the same area receives on the earth's surface. Moreover, the energy arrives around the clock.

This is why the superpowerful streams of solar rays are much more profitably "tapped" in space with the help of gigantic orbital solar stations.

Space solar-power engineering has received intensive development for the last 20 years. Thanks to the studies done by the "Kvant" Scientific industrial association, headed by corresponding member of the USSR Academy of Sciences N. Lidorenko, and by other collectives, high-efficiency photoelectric devices have been constructed which convert solar radiation into electric power. Installed on satellites and space vehicles, they provide current to other apparatus, auxillary engines and crew life-support systems. Studies on the utilization of solar power in electric rocket cruise engines for space craft are picking up speed. These engines are designed for flights into the little-accessible regions of interplanetary space--to the far planets of the Solar System, for example.

At the same time, our scientific community is working on more remote plans for the "industrialization" of near space--by this I mean space solar power stations (KES's) whose basic design has already been established. They will be immense structures weighing 20,000 to 60,000 tons, lifted over the earth to a height of 36,000 kilometers. The output of such a KES is estimated to be 5 million kW--a million kW more than the Leningrad AES, largest in Europe. Such an output will be provided by thousands of solar batteries located on the panels of the KES. The area of these panels amounts to about 50 km².

A station put into geosynchronous orbit "hangs" over a single point on the earth's surface. Illuminated by the sun 24 hours a day, it will begin to generate electric power continuously. Only once in the spring and once in the fall will it enter the earth's shadow for a brief period of time--1 hr 15 min, maximum.

Laser or microwave radiation could be used to transmit the power to the earth. The second method is preferable for a number of reasons. Microwave radiation is stable in the cold of space, freely penetrates the thickness of the atmosphere and does not suffer from fog and storm clouds. It has comparatively low losses during direct and reverse transformation. Finally, space solar-power engineering will make extensive use of microwave equipment which has already been built and developed. On the earth, this radiation will arrive at a receiving antenna whose diameter is several kilometers. Here this energy will be converted into electric current which will flow into the country's power system.

Assembly-and-installation facilities and interorbital-transport and operational space vehicles will be required to assemble KES's, deliver them to their working orbits and service them. The creation of these vehicles is no less complex a task than the construction of the KES's themselves. The key to solving this entire problem will be the supercapacity cargo launch vehicles, with whose help the KES elements will be taken from the earth to a low near-earth orbit in separate structures weighing 100 to 500 tons. Calculations show that two supercapacity transport vehicles could deliver all the elements of one KES into space in one year.

One can already say with confidence that there are no insurmountable difficulties in the realization of a design for the creation of KES's. This does not mean that they do not exist at all. The unsolved problems, however, are not theoretical, but rather technical in nature. These are the problems that we discussed in our section during the course of our work.

In particular, our section presented interesting results from theoretical and applied studies which are directed at reducing the cost of the station's equipment and which promise to insure its highly efficient operation. For example, Doctor of Technical Sciences S. Ryabikov pointed out the feasibility of sharply increasing the efficiency of solar batteries by raising the concentration of solar energy by a factor of 100 or more. Professor N. Armand and other scientists proposed a system of precision orientation for the KES antenna using radio interferometers: this system will make it possible to reduce to a minimum interference with tropospheric and broadcast communications. This interference is created by microwave radiation when a powerful stream of electrical energy is transmitted to the earth.

V. Lopukhin, doctor of physicomathematical sciences, A. Sokolov, doctor of technical sciences, A. Luk'yanov, associate professor, B. Osadin, candidate of physicomathematical sciences and other specialists spoke about new, interesting ideas for the creation of ground-based receiver-converter devices, large-scale structures, solar-ray concentrator systems and promising methods for achieving space velocities with transport vehicles.

Along with the studies of specific problems in space power engineering, scientists believe that there exist at present the prerequisites for development of a technical design for a prototype KES having a useful output of 100,000 to 500,000 kW. It should be examined as a prototype of future gigantic electric-power stations. It should confirm experimentally the operational and technical-economic characteristics of KES systems and units, the launch systems and the orbital assembly and repair facilities. The construction of such a prototype KES is a task of tremendous technical complexity. It requires orbital assembly operations and financial and material expenditures, all on an unprecedented scale. It is for this reason that international cooperation among scientists and engineers is advisable in this case.

A number of foreign states have already taken up the matter of satellite electric-power stations in earnest. In the United States, for example, a special council for space power stations has been organized. This council includes representatives from 25 major scientific and industrial organizations. Last year in France an international symposium took place whose main theme was the design for KES construction. Over 100 experts from Europe, Asia and the United States discussed technical details for the design of a satellite with solar batteries having a total surface area of 50 km². Correspondingly, the station for ground reception of the energy accumulated by the satellite should occupy 130 km². Of course, the symposium did not set any specific deadlines for realizing the project--that was not part of its task. It was noteworthy only for the fact that it gave evidence of the growing interest of various countries in space solar-power engineering.

There are already examples of international cooperation in the realization of large-scale and expensive projects. We can tell you that, on the initiative of the USSR, scientists from the USSR, the European countries, the United States and Japan have jointly begun constructing the "Intor" international thermonuclear reactor. This complex and expensive reactor, in which technical principles from the Soviet-made "Tokamak" research installation are realized, should demonstrate the practicability of obtaining electric power through controlled fusion. According to the optimistic calculations of the experts, the "Intor" will be the first in the history of mankind to jointly solve a global power problem in the interests of many countries.

In our opinion, international cooperation in research, design and other studies concerning the construction of orbital electric-power stations is a most important condition for developing the inexhaustible reserves of solar power. It is due to this cooperation of scientists' and engineers' collectives that the most progressive designs and the latest achievements of space-rocket, radiotechnical, electronic and other sectors of industry can be incorporated into the design for a prototype KES. If approximately 10 or 20 percent of the worldwide demand for power in the 21st century will be provided for by solar electric-power stations, it will be a great victory for the constructive forces of mankind.

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DEVELOPMENT OF 'ISKRA' SATELLITES BY STUDENT DESIGN BUREAU

Moscow TEKHNKA-MOLODEZHI in Russian No 6, Jun 80 pp 5-7, 41

[Article by Sergey Mostinskiy, engineer: "Earth Satellite--With His Own Hands"]

[Text] The achievements of science, technology and industry in conquering outer space are one of the basic manifestations of the modern scientific and technological revolution. The process of conquering outer space can be seen particularly clearly in the activities and aspirations of youth. Today every young person is able not only to dream about work related to the conquest of space, but can actively prepare himself for it as well. From the earliest days of childhood, rockets and planet rovers are becoming favorite children's toys and the "heroes" of their drawings. Passive involvement in activities of the space age no longer satisfies schoolchildren who dream about outer space. The games, collecting space stamps and pins, fantastic stories about flights to worlds far away--this will no longer suffice. The example of the cosmonauts, who report regularly on their difficult work in orbit, invites them to participate actively, to work on acquiring a mastery of the necessary skills and physical self-perfection. This is why we see such a broad propagation of young cosmonauts' clubs, groups engaged in model rocketry and space project design, school museums of cosmonautics. This is why the All-Union "Cosmos" contest, conducted for the 10th time already by "Designer and Model-Builder," a member of our journalistic association, has become one of the most popular competitions for the country's young engineers.

The scientific and technical creativity of students is an interesting thing. There are still years to go before they will be working in a design office (DO) for a scientific research institute; yet this young, creative energy, the acquired knowledge and skills already demand an outlet. This has given rise to student scientific societies and DO's, many of which are long famous for their original research and developments. But all this was in the traditional spheres of science and technology. What about those who dream of working in cosmonautics? To be concentrating only on their studies...

But the dream is calling! Even as long ago as the end of the 1920's, clubs for enthusiasts in rocket technology and cosmonautics began to appear in the country's higher educational institutions. They researched the problems of attaining cosmic speed, developed designs for rockets and spaceships of the future, promoted the preparation and training of personnel for a new branch of technology that did not yet exist. But now, with cosmonautics developing successfully, students are striving for much, much more. They want to be engaged in concrete projects, to be working with the real space technology, to be building satellites and rockets with their own hands.

Is this realistic in our era, when space technology still remains a unique, extremely expensive phenomenon? Students at the aviation institute and power engineering institute, both Moscow-based, were able to give a positive reply to these questions. On 26 October 1978, on the eve of the Komsomol's 60th anniversary, two student stars flamed up in orbit--the "Radio-1" and "Radio-2" artificial earth satellites (AES)--not only developed, but manufactured, tested and readied for launch as well by student hands at the cosmodrome. The "Radio-2" satellite, developed at the "Iskra" [spark] student design office, turned out to be particularly successful.

For over 20 years now, student design offices (SDO's) have been operating in Moscow's aviation institute. This form of independent, creative work for students has now received recognition at a majority of institutes that train project planners and designers of modern apparatus.

The fruitful work of SDO's in recent years is particularly evident at "Scientific and Technical Creativity of Youth" exhibitions. A large number of new, original machines and instruments have appeared, and, most importantly, practical completion has been achieved after many years of development of a number of complex instruments and devices that are not inferior to those of industrial manufacture. One such student project which has received broad recognition world wide as well as on the national level is the communications AES "Iskra-4A," which got the name "Radio-2" after its entry into orbit, and received the international radio-communications registration index RS.

Organization and Course of the SDO

The SDO "Iskra," organized in 1968 at student initiative as the first space design office of a higher educational institution, was 10 years in reaching this achievement. If one takes into account the fact that even today the industries of only 20 countries and international organizations are managing the task of building space vehicles, this cannot be considered a great amount of time. Along with Soviet efforts in this sphere, the American "Oscar" satellites of radio enthusiasts are widely known in the world--but these were developed not by students, but by employees of well-known aerospace firms, and were manufactured and tested not at the workshops and laboratories of higher educational institutions, but on the newest industrial equipment. The only difference between these and other satellites built by the firms is that the radio enthusiasts worked on them without pay, and outside of official work time.

Soviet student radio enthusiasts already had the great experience of being able to monitor AES signals beginning with the first satellite, launched in 1957. But we still did not have a special satellite for radio enthusiasts. It was the organizers of the new SDO who decided to bring this about. We were especially fortunate with respect to acquiring a scientific director. Professor Mikhail Klavdiyevich Tikhonravov, a pioneer in Soviet rocket construction, Hero of Socialist Labor, Lenin Prize laureate, Honored Scientist and Engineer of the RSFSR, assumed this position. His vast experience as a participant in the construction of Soviet space vehicles, as well as his tremendous experience as an instructor played a determinant role in establishing the collective.

The task of building a satellite, exceedingly complex in itself, was further complicated by the fact that a ground-based radio complex had to be developed in addition to the space vehicle itself, for receiving and processing information coming from the AES. However, this presented the greatest number of students the opportunity to participate in the project, and did not therefore suppress the enthusiasts. Development of space technology equipment is not, of course, an end in itself at the SDO. The most important thing is that it be a creative form of self-education, an intensification of students' professional training in a great and serious undertaking, while taking into account their interests and inclinations.

There is a great deal of room in the SDO for creative search. All of its work is conducted through student efforts under the direction of engineers, instructors and professors. Certainly, SDO work requires a total output of effort and takes up a lot of time; it is important that it not interfere with an individual's studies. The SDO takes this into account and makes maximum use of all the possibilities for combining SDO work with lesson requirements of the instructional program. This has prompted the widespread practice of student fulfillment of lesson requirements, projects, course and graduation designs that will cover SDO-related subject matter.

It is well known that design planning for a space vehicle comprises many stages. At every stage in the process of project completion there is a new accumulation of information, based on which an ever greater presentation of detail becomes possible in the features of the space vehicle as a whole, and of each of its systems. In all, eight modifications of four variants of space vehicle were developed at the design office in the search for an optimal solution, and five models were constructed. A model of the first variant of the "Iskra" AES was presented to Yu. A. Gagarin upon his visit to the SDO students. Its second modification was exhibited in 1970 at the USSR's VDNKh [Exhibition of USSR National Economic Achievements] for the anniversary display of students' scientific projects. The most active student participants were awarded USSR VDNKh medals for what they developed.

A model of the third variant of the "Iskra" AES was displayed in Grenoble in 1977 at an exhibition entitled "Higher Education in the USSR," in Havana in 1978, and at the USSR VDNKh in Moscow, where it was awarded a bronze medal. But even this variant was not the final one.

Seeing what attention directors of the institute, its party and Komsomol committees, and the Komsomol Central Committee were devoting to SDO projects, the project participants understood that their dream of launching their own satellite into orbit was assuming concrete proportions. At the same time, the experience they had re-

ceived gave them the opportunity to critically evaluate the designs that had been developed. It was clear that in order to get a positive decision for launching the student satellite, its weight, power engineering and reliability parameters could not be inferior to those of industrially manufactured models, yet at the same time could not duplicate them. Development of the fourth satellite variant--which met these requirements--was begun in 1977. A comprehensive technical analysis was conducted, the possibilities were weighed and a conclusion drawn--the first vehicle must be simplified to the maximum possible extent and contain only those systems which would provide for its functioning in orbit and enable the necessary information to be received. To reach this conclusion, however, the entire gamut of SDO experience was necessary.

Development of "Iskra" Satellite Design

Development of the first AES variant was begun in 1968 and 1969. An acceptable design configuration scheme would have to satisfy durability, thermal and technological requirements. Choice of vehicle design took place not only behind the Kuhlman drafting unit, but behind computer consoles as well, where thermal processes were modeled, and aerodynamic and ballistic calculations made.

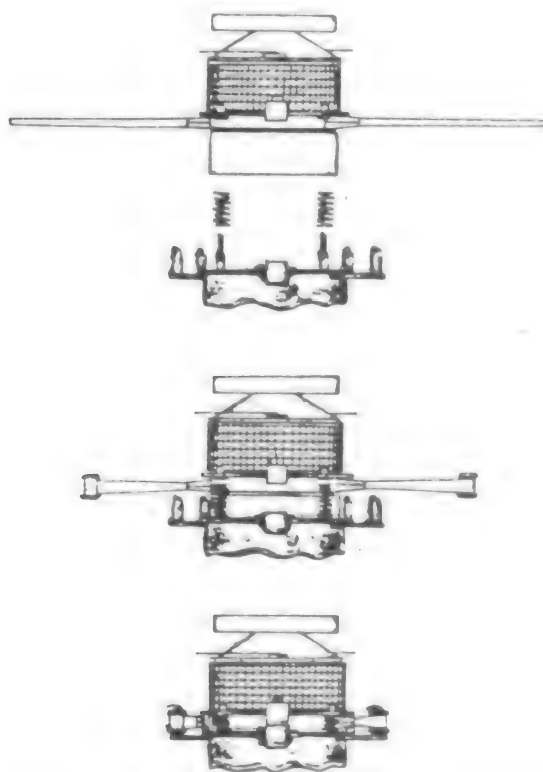
The technical equipment then existing in workshops of the Moscow Aviation Institute imposed a significant restriction with regard to seeking efficient variants.

Various functions of the same design elements were successfully integrated in the first design plan. A tube positioned along the axis of the satellite served as the power element. Supports were located at its edges, to which was attached the housing itself. This consisted of pentagonally-shaped plates mounted in the form of a dodecahedron. In the tube was positioned a system for launch vehicle separation, and a rod which had to slide out after the satellite's entry into orbit, changing its moment of inertia. As a result, the satellite had to turn, the rod's axis swiveling in a direction towards the local vertical under the effect of gravitational forces. A single-axis gravitational system of orientation enables one side of the satellite to be oriented on the earth, providing for use of the directed antennas. However, it is impossible to use this system to orient on the sun. Solar battery panels were therefore positioned evenly along the sides of the housing. The electronic equipment for "Iskra-1" was placed in a hermetically sealed casing. The problem of hermetic sealing forced building of a cumbersome design for the casing, which resulted in a substantial increase in its weight and a more complicated on-board cable network. In addition, within the satellite's small dimensions, its central power element added an awkward cylindrical shape to the electronics assemblies; maintaining a mode of temperature conditions by the external coloration of the casing brought about too great a variation of possible temperatures within it.

Although completion of the first satellite design did not turn out successful enough so as to be able to pose the question of launching it, it can now be said that this design played a determinant role in the establishment of the SDO. Experience acquainted us with the true complexity of fashioning equipment for use in outer space, and at the same time we felt that we were capable of accomplishing the assigned mission. We saw the new directions in which we had to follow.

Information came to light here that contemporary electronic devices were capable of operating in super-vacuum conditions. We therefore concentrated a significant portion of our efforts on the development of such equipment, efforts conducted in close cooperation with students of the Moscow power engineering institute. As a result, a design appeared in 1973 for a telegraph-telemetry, ultra-short-wave equipment set, the "Telegraph-S," which enabled us to eliminate hermetic sealing of the satellite's housing.

For the "Iskra-2" satellite, developed in 1973-1974, the instrumentation was placed on two fabric-laminated plates. Heat flow between the internal equipment and the housing was reduced due to a decrease in the heat conductivity of the construction materials. Elements of the housing, made in the shape of equilateral triangles, became the power component of the design. Housing elements of this shape permitted the satellite's dimensions to be changed quickly, due to installation of additional belts, pulled together out of the triangles. In order to increase the satellite's reliability it was decided to mount another radio-telemetry instrumentation system. This one would operate in the short-wave band. Upon satellite separation from the launch vehicle, a pre-programmed device would start functioning and give instructions for the short-wave antennas to open up and both telemetry systems to switch on.



Launch Vehicle Separation Sequence
for the "Radio-2" Satellite
and Opening of its Antennas

Design plans for the "Iskra-3" satellite appeared in 1975-1976. Without any change in the satellite dimensions, the area of the solar batteries was almost doubled. Interesting decisions were made during the construction of radio-electronic instrumentation and the testing phase for the antenna-feeder system. During these years the SDO began building the first complex of monitoring and measuring equipment for pre-launch ground testing; techniques and procedures for the testing were developed on the "Iskra-2" and "Iskra-3" vehicles.

In 1977, in order to draw nearer our goal--the actual launch of a student satellite into outer space--we decided to simplify the task even further, and rather than build an autonomous satellite, we would construct a non-detachable block unit that could be mounted on the upper stage of a launch vehicle for joint launching.

The significant experience gathered through SDO work and the arrival of new, talented students and young specialists permitted completion of planning and design development for the non-detachable block unit "Iskra-N" in short order. From the very beginning, development of the design configuration was conducted taking into account the problem of temperature control in the instrument block. As a result, the construction design for the block was changed several times. The first design variant envisaged mounting the equipment internally on a fabric-laminated plate, as was the case for the second and third "Iskra" vehicles. The required durability was achieved by increasing the thickness of the plate. As a result, the heat conductivity of the plate turned out to be so great that, even with negligible temperature differences between the housing and internal equipment (only 10-20 degrees), the heat flux could considerably exceed the heat release of the equipment within. The non-detachable block unit was threatened either by the cold of outer space, if it happened to be in shadow, or by overheating, if it were subject to the sun's rays. The design configuration underwent a number of changes--increasing temperature resistance of the construction materials, connecting the internal equipment with parts of the housing, reducing the overall weight of the vehicle. The internal equipment was anchored in the housing on fabric-laminated supports, which resulted in lesser heat loss. The equipment itself was joined onto a monoblock unit, densely packaged on a metallic plate. Large temperature differentials could not occur in the monoblock. At first only a tiny activity volume was allocated for the vehicle. The new power configuration enabled the weight of the housing to be reduced significantly. On the whole, the "Iskra-N" design turned out so well that experts who examined it recommended that the SDO return to it as a basis for constructing an autonomous satellite.

from the Launch Into Orbit

In October 1977, the SDO began its work in designing the "Iskra-4A" AES. As might be expected, new problems (compared with "Iskra-N") appeared during its development. But they were quickly "overgrown" with ideas from all sides, and seemed to find their own solutions. The experience of many years and several generations of students working in the SDO was making itself felt. Heat-flow sensors were mounted on the "Iskra-4A" housing, providing for measurement of the heat flow from the earth and sun, and determination of direction to the earth and sun in the satellite's coordinate reference system. A new radio enthusiast's relay-retransmitter appeared on board the satellite. Although we wanted to outfit the satellite with the radio relay we developed at the "Iskra" SDO, it turned out that the RS-1 radio-instrumentation relay built at the Space Technology Laboratory (STL) of the USSR Radio Sport Federation

under technical direction of L. M. Labutin, time-and-again a USSR radio sport champion, strongly surpassed all previously developed designs in its technical features. The Moscow radio enthusiasts Kalugi and Molodechno participated in the painstaking, sometimes selfless work on the equipment. The numerous problems that arose in conjunction with the coming radio-enthusiast satellite launches were resolved satisfactorily, thanks to the Coordinating Committee for Satellite Communications, established under the auspices of "Radio" magazine, under the chairmanship of chief editor A. V. Gorokhovskiy. Along with the Komsomol Central Committee, the DOSAAF Central Committee also rendered a great deal of assistance and support during all stages of the satellite project.

Along with developing and building the on-board radio relay equipment, the STL collective established its own well-equipped ground control and receiving station in Moscow.

From the very beginning of joint operations between SDO and STL on the "Iskra-4A" design, friendly and businesslike relations were established.

Installation of solar batteries (phototransducers) on the satellite resulted in an increase in its orbital life to three months. The thermal regulation system, based on absorption of heat by a heat accumulator, didn't work out. The problem was solved by creating a semi-active, thermal regulation system. A cylindrically-shaped radiator-emitter was mounted on the satellite, whose temperature was kept low enough by its white enamel coloration. A metallic heat conduit connecting the instrument-block plate with the radiator-emitter would open and close on command of the electronics block unit, depending on the temperature of the internal equipment.

The "Iskra-4A" vehicle ran a complex course of ground testing. It went through its trials on Earth, and, when necessary, each system was checked out--each block unit, each assembly, each junction. The trials became complicated by the fact that neither the SDO nor STL had a sufficient testing background or the necessary experience--nonetheless, every difficulty was satisfactorily overcome.

It is difficult right now to express the emotions felt by the student brigade that prepared the satellite for its launch at the cosmodrome, the emotions felt by the entire SDO collective upon picking up signals from outer space, transmitted from their "champion," and upon receiving words of genuine gratitude from radio enthusiasts all over the world. For eight months the "Radio-2" satellite functioned in its orbit, our "Iskra," the spark our students are ready to transform into the flame of a permanent communications system for radio enthusiasts.

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USO: 8144/1509

PROPOSAL FOR SURFACE-SPACE RADIOINTERFEROMETER WITH BASE UP TO ONE MILLION KILOMETERS IN LENGTH AND COHERENT RADIO COMMUNICATION BETWEEN TELESCOPES

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 5, Sep-Oct 81
(manuscript received 20 Oct 80) pp 763-772

ANDREYANOV, V. V. and KARDASHEV, N. S.

[Abstract] The authors examine the design principles and characteristics of an interferometer for investigating galactic and extragalactic radio sources formed by a surface radiotelescope and a space radiotelescope which is placed on a high-apogee (0.1-1 million kilometer) artificial earth satellite. The interferometer, having a superhigh resolution (up to 10^{-5} second of angle in the centimeter range of radio waves), is planned for operation in real time. The heterodynes of the receivers for the space radiotelescope are synchronized using a radio link from a surface frequency standard, at the same time being a reference generator for the receivers of the surface radiotelescope and the coherent communication receiver for data from the artificial earth satellite. The signals from the radio source, received by the space radiotelescope, are transmitted to the earth in binary form. Frequency variations of the samples and the transmitter carrier frequency are also formed from the same reference oscillation received from the earth as the variations of the heterodyne frequencies of the space radiotelescope. Such a combining of radiotelescopes and a coherent two-directional radio communication channel into a single complex makes it possible not only to reduce the phase uncertainty of radio waves signals received by the space and surface radiotelescopes, but also to ensure "local" measurement of the momentary length of the base and synchronization of the measurements and also the timely delivery of information for processing. The principal characteristics of the radiointerferometer are calculated: energy response, with angular resolution taken into account, errors in synchronization of the heterodynes and moments of measurement of the space and surface radiotelescopes, errors in orientation of the antenna of the space radiotelescope, parameters of the radio channel for transmission of signals from the space radiotelescope to the earth and approximated form of the noise spectrum. Figures 3, tables 1; references 3: 4 Russian, 1 English.

PROBLEM OF CONTROLLED SPACECRAFT ENTRY INTO THE ATMOSPHERE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 4, Jul-Aug 81
(manuscript received 12 Jul 79) pp 634-638

KAYDA, V. K.

[Abstract] The author studies the conditions for controlling the landing aspect of a spacecraft into the atmosphere. He limits himself to predominantly stabilized spacecraft having small angles of attack and yaw, assuming otherwise the effect of the reactive moments and forces can destabilize them. Using equations of spatial motion of a spacecraft, he concludes that an axially symmetric spacecraft will possess dynamic stability if its radius of inertia corresponding to its equatorial moment of inertia is less than any distance from the center of mass to the center of pressure. References: 3 Russian, 3 Western, [7-11746]

UDC 62-50:62-1.01

SPATIAL OSCILLATIONS OF AXIALLY SYMMETRIC VEHICLE WITH ARBITRARY ANGLE OF ATTACK DURING DESCENT INTO PLANETARY ATMOSPHERE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 7, Sep-Oct 81
(manuscript received 30 Apr 80) pp 680-687

ORLOV, V. G., TIMBAY, I. A. and BOYKO, V. V.

[Abstract] A study was made of oscillations of an axially symmetric space vehicle during descent in a planetary atmosphere with arbitrary angle of attack. The Volosov method (V. M. Volosov, "Some Types of Computations of the Theory of Nonlinear Oscillations Related to Averaging," *IZH. VUZOV. MATEM. I MATEM. FIZ.*, Vol 3, No 1, pp 3-51, 1961) was used in deriving asymptotic equations of motion in an integrodifferential form for space vehicles of an arbitrary axially symmetric configuration. Under the condition that the coefficient of an aerodynamic restoring moment is represented by an almost sinusoidal dependence on the angle of attack these equations are reduced to an ordinary differential equation. It is shown on the basis of numerical computations that the derived equations are also applicable when there is a substantial difference between the restoring moment coefficient and the sine of the angle of attack. An approximate formula is derived for determining the amplitude of oscillation of the angle of attack in the case of motion along the plane. Figures 4; references: 4 Russian. [7-15302]

GRAVITATIONAL ORIENTATION OF ROTATING SATELLITE

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 4, Jul-Aug 81
(manuscript received 3 Nov 80) pp 499-512

SARYCHEV, V. A. and SAZONOV, V. V.

[Abstract] The authors analyze one method for achieving uniaxial gravitational orientation of a satellite that is close to being dynamically symmetrical. They set up equations of motion and compare the gravitational orientation of satellites that are dynamically symmetrical and close to it. They also carry out a numerical investigation of the gravitational orientation conditions for the latter, as well as the stability of its periodic revolutions. Figures 8; references 9: 7 Russian, 2 Western.
[7-11746]

UDC 1.380

UNIAXIAL GRAVITATIONAL ORIENTATION OF ARTIFICIAL SATELLITES

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 19, No 5, Sep-Oct 81
(manuscript received 22 Dec 80) pp 659-673

SARYCHEV, V. A. and SAZONOV, V. V.

[Abstract] The authors investigate the motion of a satellite close to dynamically symmetric about its longitudinal axis in a uniaxial gravitational orientation regime. In nominal unperturbed motion the longitudinal axis of the satellite is directed toward the earth. With small initial errors in orientation the motion of the satellite relative to the longitudinal axis constitutes slow oscillations or slow rotation on which are superposed rapid oscillations with a small amplitude. The integral surface of slow motions is constructed in the form of formal series in powers of a small parameter characterizing the deviation of the satellite from dynamically symmetric. The motion on this surface is described by a second-degree differential equation coinciding in the first approximation with the equation of a mathematical pendulum. A numerical investigation of the slow periodic motions is presented. It is shown that in some cases such motion approximates well the perturbed motion of a satellite about its longitudinal axis. Figures 10; references: 4 Russian.
[24-5303]

SPACE APPLICATIONS

COST-EFFECTIVENESS OF GEOGRAPHIC SURVEYING FROM SPACE

Moscow EKONOMIKA I MATEMATICHESKIYE METODY in Russian Vol 17, No 5, Sep-Oct 81
(manuscript received 5 Jan 81) pp 920-935

[Article by M.Ya. Lemeshev, Yu.V. Sukhotin and A.F. Demidov]

[Text] The latter half of the 20th Century has been marked by a vigorous scientific-technical revolution. Its achievements have radically altered conditions for the expansion of productive forces and raised new scientific and economic problems.

One example of this is the exploitation of space. Although it has been only a quarter of a century since the first artificial earth satellite was launched, mankind has obtained an enormous amount of information on nature and the processes taking place in the environment. New knowledge has been amassed with astounding speed, enriching virtually every area of science. Our mastery of space has given rise to such scientific disciplines as space biology and medicine, space materials science, satellite-based geographic research, and so forth. The exploitation of space is also stimulating the development of technology and economics. Specifically, it not only has created one of the largest branches of modern industry but has also had the somewhat unexpected result of demonstrating the real possibility that this area will become a completely "self-supporting" subdivision of the national economy. In the early stages of the development of space technology, it might have seemed to represent "pure" expense in economic terms, diverting economic resources without return (if one ignores the indirect positive influence it exerts on the economy by increasing the sum of our scientific and technical knowledge). It was soon found, however, that some (applied) areas in which space technology can be utilized may already be having a major economic effect, one measurable in monetary terms.

Although a variety of attempts have been made to evaluate the potential scale of this effect on a worldwide basis, the figures most frequently mentioned are from 60 to 150 billion dollars annually, including 20-40 billion for space-based communications, 20-60 billion for meteorology, and 20-50 billion for research on the Earth's natural resources (RENRR). The latter category includes various type of information gathering from space on natural and industrial features, as well as rapid monitoring of natural phenomena of importance for economics and the actual processes involved in industrial activity. This sector of space economics, which is the main topic of the present article, is therefore perhaps more accurately termed space-based geography.

It is self-evident that evaluation of the cost-effectiveness of the exploitation of space requires comparison of results with expenditures. The published data are quite incomplete and permit only approximate estimation of the order of magnitude of the parameters in which we are interested. Thus, annual appropriations for the US space program amount to 6-7 billion dollars (with a considerable proportion going for nonmilitary purposes), while France, the FRG, Japan, and England together budget an additional 0.7-1 billion dollars, i.e., the developed capitalist nations presently expend 7-8 billion dollars annually on all types of space-related activities. It would apparently be justified to assert that the potential economic consequences of the application of space technology is an order of magnitude greater than total actual expenditures for this new branch of the world economy.

However, such a comparison of actual expenditures with potential economic results has fundamental intrinsic inaccuracies. On one hand, the cost of building and operating systems with economic applications is only a small fraction of total expenditures: it accounts for less than 10% of appropriations for civilian space programs in the USA and 20-30% in other capitalist nations [1, p 17; 2, pp 66-68]. On the other hand, predictions of potential economic benefits (with consideration given to the possibility of saving production costs and time, reducing losses of finished products and resources, and expanding production) in industries that utilize satellite data, although based on information on the current scale of economic activity, still rest on the hypothesis that all the requisite organizational and technical measures pertaining to space-based information services and communications will be implemented. This naturally requires far more extensive applied satellite systems than those now in operation or being developed and hence far greater expenditures. It is very difficult to estimate the total costs involved, because of the rapid progress being made in the aerospace industry.

Under these conditions, data on specific systems with economic applications that are presently in use are more reliable for evaluation of cost-effectiveness. Thus, capital investments in the Landsat natural-resources program (USA) over the period 1972-1978, which saw the launch of three experimental satellites, amounted to 650 million dollars. The annual costs of system operation (determined on an adjusted-expenditure basis) are 60-80 million dollars, while the economic benefits are 420-960 million dollars per year, i.e., exceed expenditures by a factor of 7-12 [1, pp 188, 190]. Calculations made for the near future (through the mid-1980's) characterize a system of the Landsat type with two satellites simultaneously in orbit, giving the following figures: total capital investments for system construction and operation over a period of 16.5 years will be 621 million dollars, adjusted costs will be 45.6 million dollars annually, and projected economic benefits will be 1028 million dollars annually. The corresponding figures for a similar system with three satellites are 853 million, 61.9 million, and 1973 million dollars [1, p 202].

Thus, annual profits exceed adjusted costs by a factor of 22.4-31.8. It is noteworthy that similar ratios are typical of most satellite systems with commercial applications, both Soviet and foreign. According to expert estimates, total costs for development of the RENR system have already been recovered; savings will exceed expenditures by a factor of 12-17 in the near future and will subsequently rise at an increasing rate [3, pp 5-9].

The assertion that economic returns will be ten times or more greater than expenditures is thus, under current conditions, more properly made with respect to the commercially useful area rather than for total outlays for exploitation of space. However, taking into account the proportion of total expenditures accounted for by systems with commercial applications, it is obvious that the absolute economic return is in the process of becoming sufficient to completely cover all the costs of the space program. The prerequisites have thus been created for conversion of the "space industry" (primarily those sectors of it that have commercial applications) to a "normal" industry that operates under the same economic and organizational regime as other branches of the economy. In the capitalist nations, this trend toward "commercialization" of space activities is taking a number of forms: expanding sales of satellite-gathered data, leasing of satellite communications channels, launches requested by governmental agencies, commercial firms, and foreign customers, orders for construction of ground stations for RENR and communications systems, and broad involvement of private capital. During the 1970's, capital investments by commercial corporations (1142 million dollars) accounted for about one-third of all funds allocated to satellite systems with commercial applications. In recent years, as many as two-thirds of all NASA launches have been on a commercial basis. Receipts for putting payloads into orbit in 1976 were 264 million dollars. Foreign revenues received by NASA under different types of commercial contracts over the period from 1965 to 1977 were 2.17 billion dollars. Income from the commercial INTELSAT global satellite communications system runs approximately 200 million dollars annually [1, pp 38-42, 48, 59-62, 65].

To the present, all expenditures for the construction and operation of satellite systems with commercial applications in the Soviet Union have been financed by budgetary appropriations. However, the rapidly expanding range of organizations interested in data collected by remote sensing of the Earth from space (expected to reach 1200 in number [3]) and the ever-increasing opportunities for obtaining a real economic return from the utilization of these data make proposals that a self-supporting system be set up and particularly that satellite-gathered data be disseminated on a fee basis quite timely. There is no doubt that the requirement of self-support will have a beneficial effect on the overall effectiveness of the commercial and technical decisions made in connection with space activities.

The switch to self-supporting operation requires a different approach to economic analysis than that still in use in the industries and organizations that utilize space technology. Predominant at present are a posteriori economic calculations intended to confirm the economic advantages of existing systems or very general and vague appraisals of the advantages that might be derived by different branches of the economy were the current deficiencies in their information services (incompleteness, inaccuracy, and irregularity of data, delays in furnishing information, etc.) eliminated by use of space technology. The cost-accounting approach necessitates determination of the economically permissible and justified levels to which information parameters should be improved and establishment of the most economical designs for satellite systems and combinations of these systems with traditional (ground and aerial) observation and communications facilities. This requires more timely, accurate, and specific economic calculations, since they provide the basis for technical and organizational decisions. In other words, we must move from "economic acknowledgement" of space technology to regularization of its economic foundation. One material prerequisite to this transformation is the ever-increasing

variety of possible design solutions that can be utilized both in making up the satellite systems themselves (orbital parameters, number of artificial satellites, composition and parameters of on-board equipment, and methods for generating, transmitting, and processing information) and in creating various combinations of these systems with terrestrial RENR and communications facilities.

There are, on the other hand, major factors hampering the development of such an economic approach. Systems with commercial applications remain closely associated with other "noncommercial" sectors of the space program and make use of only a small proportion of the effort and resources directed at exploitation of space. This cannot help but reduce the impetus to seek the most economical methods for use of the small portion of the nation's economic resources involved, particularly since the large economic returns from applied systems have not as yet lost the charm of being a somewhat unexpected "byproduct" of activities known beforehand to be non-self-supporting. Nevertheless, a switch to the customary economic mode for operation of systems with commercial applications is also necessary because, when considered on an absolute basis, the costs of their development are very substantial and because these systems are becoming increasingly specialized for provision of continuing services to specific types of industrial clients (Table 1).

The economic calculations currently made for the space program are generally far from meeting the need for provision of an economic foundation for space technology. Their main defects are a lack of correlation between volume and structural parameters and unreliability of the initial data employed.

It is readily seen that one of the factors responsible for differences in forecasts is discrepancies in the makeup of the areas of information utilization under investigation. The same situation occurs within these areas. Thus, in evaluating the benefits resulting from utilization of satellite information in American agriculture (which different sources estimate as amounting to from 5 million to 13 billion dollars annually), the Richards Planning research corporation proceeded from the possible implementation on the basis of satellite data of a complex of measures that would permit a two-thirds reduction (by 4,6 billion dollars per year) in harvest losses to crop pests and diseases. An analysis by IBM, which calculated the "agricultural benefits" as totalling 400 million dollars annually, did not include the so-called "crop diseases" at all. Equally large discrepancies arise as a result of differences in the formulas used for the relationships between natural and anthropogenic processes, e.g., the influence of snow cover, water supply, and species on yields of hydroelectric generation, as well as from disagreements over the extent to which the forecasting of natural phenomena can be made more accurate by use of satellite data. Thus, the AES and ECON research organizations used the same computational model (with the economic benefits being proportional to the square of the decrease in forecast error) in evaluating agricultural benefits. However, a difference amounting to a factor of two in the initial-error estimates led to a difference amounting to a factor of four in the anticipated economic effects [4, p 52].

Such calculations serve as the starting point in providing an economic justification for introduction of space technology. Improvements in this preliminary stage of economic analysis are to be expected (or required) from specialists in the natural sciences and engineering, i.e., geophysicists, biologists, engineers, agricultural engineers, etc. However, the quality of the decisions made regarding the development

Table 1

Benefits of Commercial Utilization of Satellite Information on a World Scale, Billions of Dollars per Year and Percentage of Total* (from Calculated Forecasts) [4, p 47; 5, p 235]

Area of application for satellite information	Country and Date of Forecast									
	USA					USSR				
	1965	1966	1967	1968	1974	1978	1974	1978	1978	1978
1. Agriculture	0.10	59.0	7.4	33.0	47.9	45.4	40.3	79.8	5.0	23.0
2. Forestry	-	-	2.1	9.5	57.6	54.6	0.6	1.2	-	-
3. Fishing	0.05	29.4	3.9	17.0	-	-	4.3	8.5	9.0	41.3
4. Geology	0.01	5.9	2.1	9.5	-	-	-	-	3.5	16.0
5. Cartography	-	-	0.8	3.6	-	-	-	-	0.8	3.7
6. Hydrology and oceanography	0.01	5.9	5.9	26.6	-	-	0.4	0.8	3.5	16.0
7. Environmental protection	-	-	-	-	-	-	5.0	9.9	-	-
Total	0.17	100.0	22.2	100.0	100.0	100.0	50.6	100.0	24.8	100.0

*Beneath each year, the figure on the left represents billions of dollars and that on the right represents the percentage.

and utilization of space technology depends in no small way on the economic methods employed for evaluation and comparison of design variants for the entire RENR system, including its satellite subsystem. While such methods have not played a major role in calculations directed at "economic acknowledgement" of space technology (since the variants themselves were essentially selected independently of the results of the calculations), the switch to economically justified decisions means that the procedure employed for evaluation of different variants becomes no less important than the quality of the initial data.

It is noteworthy that current space-economics calculations belonging to the comparative-effectiveness category (generally involving comparison of the specific costs of satellite and non-satellite RENR information) usually fail to discern the specifics of the advantages of satellite geographic surveying for the national economy. When expressed in verbal form, descriptions of these advantages are dominated (and properly so) by the unique properties of satellite information systems: their enormous information output, high repeatability, currentness of information flow, virtually unlimited range of viewing fields (from local to global), provision of information on regions difficult of access, direct generalization of observations, clear delineation of the macrostructure of features on the Earth's surface, etc. All these characteristics will make it possible to radically improve the organization of many economic activities (agriculture, marine fishing, mining of useful minerals, marine transportation, etc.) and to formulate and solve a number of new economic problems not amenable to the use of traditional information sources. These advantages are, however, blurred by comparative-effectiveness calculations: satellite information systems are generally considered merely to be a less expensive tool for obtaining information identical in content and volume to the information "output" of traditional RENR methods. Clearly artificial and unrealistic assumptions underly this viewpoint.

Organizations dealing with the introduction of satellite information systems most frequently use the well-known formula for annual economic effect

$$E = (C_1 - C_2)A_2 \quad (1)$$

where C_1 and C_2 are the adjusted costs of producing a unit of goods (services) with the standard and new technologies and A_2 is the annual output of goods (services) produced by using the new technology [6, p 8]. This formula is quite correct if the product manufactured through use of the two technologies has identical characteristics in terms of use and the output volume for the old technology (A_1)

is the same as A_2 , i.e., the two technologies are completely interchangeable. The requirement that the product be user-compatible and the treatment of the old technology as replaceable are stipulated in current methodological recommendations [6, 7-10]. These correspond most closely to situations in which industrial facilities with a fixed "rated capacity" are completely reequipped. Here E represents the gross savings in production costs resulting from the switch to the new technology. On the other hand, violation of the condition that the goods (services) be identical with respect to output volume and quality causes (1) to become a somewhat arbitrary index, possibly concealing either overestimation or underestimation of the actual cost-effectiveness of the technology to be introduced.

The analog of A_2 generally employed in economic calculations for space technology is S_{spac} , which represents the area of the Earth's surface surveyed by satellite information systems over the course of a year. In calculating the annual effect from Eq. (1), the specific costs C_1 for traditional RENR methods, calculated from the actual area S_{tr} covered by these techniques ($S_{\text{tr}} \ll S_{\text{spac}}$), are extrapolated to the area S_{spac} . Such calculations are fundamentally unreliable, since it is hypothesized that the technology is completely supplanted, a hypothesis that does not conform in terms of either scope or qualitative characteristics to the actual situation with respect to formation of satellite information systems. Differing from one another in the index S_{spac} (which can be so large as to represent coverage of the entire surface of the Earth, depending on the inclination of the AES orbit), these systems are not comparable in terms of information output to aerial observation and other traditional RENR methods. Thus, a system that provides a coverage area of 125 million km^2 with one satellite in operation can provide information on each section of this surface 21 times per year; the annual productivity of the system is 94,500 photographs with each frame covering an area of 35,000 km^2 [2, p 81]. When the typical productivity indices for aerial photography (40,000-360,000 km^2 per aircraft per year) are taken into consideration, it can be seen that the "replaceable technology" for such a single-satellite system must be estimated at 20,000-80,000 aircraft, a figure that is obviously incorrect. Determination of "cost savings" on this basis is as pointless as, e.g., the assumption that the work force potentially employable is augmented by the total number of workers "freed" by use of computers even though one knows this number to be several times the entire population.

This shortcoming is not so strikingly evident in most calculations made in practice, since the fixed amount of work performed is not the global productivity of satellite information systems but the area of the specific regions to be studied. In this case as well, however, extrapolation of the "traditional" specific costs C_1 to the area S_{spac} means a computational expansion of nonspace RENR operations by tens or hundreds of times, which is either physically impossible or, in any event, scarcely possible with the same level of specific costs C_1^* . Some fields (e.g., geological prospecting) make use of modified versions of Eq. (1) that permit determination of more realistic "annual-effect" values by not considering S_{tr} and S_{spac} to be identical.

Satellite and traditional RENR systems cannot be compared in terms of information output and are far from identical with respect to the content of the information they yield. Terrestrial methods have their own unduplicatable advantages, such as far greater detail, the possibility (in "ground" methods) of direct contact with the features to be investigated (e.g., chemical analysis and so forth), etc. Traditional information and satellite data supplement rather than duplicate one another:

*The switch to methods for determination of the cost-effectiveness of RENR techniques that are more realistic than the "complete-replacement effect" requires calculation of specific costs as a function of scope of operations: $C_1 = C_1(S_{\text{tr}})$ and $C_2 = C_2(S_{\text{spac}})$.

the degree of interchangeability between them cannot be total (e.g., satellite information systems are free of the need to compile overall descriptions of major features by laborious "assemblage" of many detailed observations). Moreover, full functioning of satellite information systems requires that terrestrial information sources be incorporated into them; these can be ground "polygons," airborne "platforms" (airplanes, helicopters, balloons), etc.

The correctness of considering satellite information systems solely as a "replacement technology" is confirmed by the development of a new category, that of "new problems" whose solution would be utterly impossible without use of satellite information. Thus, the establishment of 200-mile zones has necessitated vast enlargement of the marine-fisheries aquatorium. "While fish location presently should involve search operations carried out over several million square kilometers of ocean surface (even though this cannot actually be accomplished), the near future will see a need for daily monitoring of up to 200 million square kilometers of aquatorium, which would require several thousand vessels equipped with the technical tools currently in use. This approach is easily seen to be unrealistic" [5, p 174].

The unrealistic character of the complete-replacement hypothesis means that formulae of the type in Eq. (1) cannot serve as the economic basis for space technology; they are also, as a rule, erroneous as a measure of the "actual effect." As for "new problems," recommendations made in 1977 include a formula for calculating the annual economic effect resulting from the manufacture of a new product [6, p 11]:

$$E = (P - E_n C) A_2 \quad (2)$$

where P is the profit from sale of the new product, C is the specific capital investment, E_n is the effectiveness norm, and A_2 is the output of the new product (it is evident from the nature of the problem that $A_1 = 0$).

Three methodological approaches are encountered in foreign calculations for the economics of space technology: a) the method of equal opportunity, which is analogous to Eq. (1); b) the method of new opportunities, in which E is, as in Eq. (2), the difference between the price of the product and the adjusted costs of its production (with no constraints on output or cumulative expenditures); c) the method of equal budgets, which is an intermediate technique [1, pp 139-140]. In the latter approach, different types of technology are compared on the assumption that the expenditures for them will be equal but that their output levels will differ. While, like Eq. (1), the equal-budget method is related to the complete replacement hypothesis, it also has something in common with Eq. (2), which requires that production be measured in terms of value, in contrast to Eq. (1). It is the latter fact that probably accounts for the strong preference currently given to calculations based on Eq. (1). Since there is no adequate pricing system for "intermediate output," calculation of "sales" or "revenues" requires determination of the economic consequences of the use of information in different areas of the economy. Since we are still dealing with an extremely fragmentary, contradictory, and unreliable set of estimates. On the other hand, it is sufficient to establish the fact of possessing the information for calculations with Eq. (1), assuming that the level of expenditures (planned or estimated by experts) demand for it, however low, has been agreed by a number of foreign studies (Table 2), the area of application of the type of Eq. (1) can be correctly employed in extremely restricted cases [1, p 140].

Table 2. Structure of Anticipated (Mid-1980's) Effect of Satellite Information Systems by Problem Type, % of Total for Line

Branch	Problem types		
	Equal oppor- tunities	Equal Budgets	New oppor- tunities
Agriculture	3.0	31.7	65.3
Forestry and pasture management	4.3	4.0	91.7
Inland water resources	36.6	35.0	28.4
Meteorology	27.1	2.9	70.0
Total	11.8	30.6	57.6

It should be noted that the first two areas listed in Table 2 account for 81.3 percent of the anticipated economic effect.

When joint utilization of different types of technology is necessary (rather than complete replacement of one technology by another), economic substantiation methods should aid in seeking the most advantageous type combinations. It can be demonstrated that formulas of the type of Eq. (2) permit solution of this problem, although only when rather stringent technical-economic prerequisites are met. In attempting to generalize Eq. (1), let us consider the problem of finding the minimum cost Z of producing a predetermined amount of product Q_0 by different technological methods j :

$$Z = \sum_{j=1}^n Z_j(q_j) \rightarrow \min \quad (3)$$

with the conditions $\sum_{j=1}^n q_j \geq Q_0$, $q_j \geq 0$, $j=1, \dots, n$.

Here q_j is the product output sought, as determined by each method j , $Z_j(q_j) = C_j(q_j) + EK_j(q_j)$ is the adjusted cost of the entire output q_j [rather than the cost per unit product, as in Eq. (1)], and E is the adjustment norm. For the sake of simplicity of notation and retention of a clear relationship to the commonly employed formulas in Eqs. (1) and (2), the problem in Eq. (3) is not the most general formulation. It might deal with a multiplicity of products and time periods (specifically substituting "annual" adjusted costs and "integral" effects into it). However, the conclusions with which we are concerned remain in force for this expanded problem.

Equation (1) describes a special case of the problem in Eq. (3), that in which $j = 1, 2$ and $Z_j(q_j) = C_j$ with Z_j remaining constant. In this case, the method with the lowest specific costs, e.g., $j = 2$, should be used for the entire output Q_0 ; if $C_2 < C_1$, then $q_2 = Q_0$ and $q_1 = 0$. Conversely, in the general case of Eq. (3), permissible solutions to the problem (variants) include not only the values $q_{10} = Q_0$

($q_j = 0, j \neq j_k, j_k = 1, \dots, n$) but also all possible combinations of nonzero q_j for simultaneous use of different "types of technology." The value of each q_j is more properly referred to not as a variant, as in Eq. (1), but as a solution "subvariant." Even with only two types of technology, there is an infinitely large number of solution variants for Eq. (3) rather than just two.

The question of whether one can find the most advantageous values of the "subvariants" q_j without solving Eq. (3) as a whole is of great practical interest. This is (inaccurately) termed selection of variants without constraints on production and costs.

Representing Eq. (3) in the equivalent form

$$Z_p = \sum_{j=1}^n Z_j(q_j) + p \left(Q_0 - \sum_{j=1}^n q_j \right) \rightarrow \min, \quad q_j \geq 0, \quad j=1, \dots, n,$$

we write the necessary optimization conditions

$$\frac{\partial Z_p(q_j^*; p^*)}{\partial q_j} = \frac{dZ_j}{dq_j} - p^* \geq 0, \quad \frac{\partial Z_p(q_j^*; p^*)}{\partial q_j} q_j^* = 0, \quad j=1, \dots, n, \quad (4)$$

$$\frac{\partial Z_p(q_j^*; p^*)}{\partial p} = Q_0 - \sum_{j=1}^n q_j^* \leq 0, \quad \frac{\partial Z_p(q_j^*; p^*)}{\partial p} p^* = 0. \quad (5)$$

If the optimum production estimate $p^* > 0$ (i.e., $\sum_{j=1}^n q_j^* = Q_0$), we can state the problem

$$E = p^* \sum_{j=1}^n q_j - \sum_{j=1}^n Z_j(q_j) \rightarrow \max, \quad q_j \geq 0, \quad j=1, \dots, n, \quad (6)$$

without any constraint on production.

The necessary conditions for Eq. (6) are

$$\frac{\partial E(q_j^*; p^*)}{\partial q_j} = p^* - \frac{dZ_j}{dq_j} \leq 0, \quad \left(p^* - \frac{dZ_j}{dq_j} \right) q_j^* = 0, \quad j=1, \dots, n. \quad (7)$$

Eq. (7) is to be used to be identical to those in Eq. (4), while the quantity p^* corresponds to the value in Eq. (5). It should be noted that, for every $q_j^* > 0$, the condition $\partial E / \partial q_j = p^*$ is satisfied, this being the necessary condition for optimality of the local subvariant-selection problem

$$E_j = p^* q_j - Z_j(q_j) \rightarrow \max \quad (8)$$

It is evident that local maxima E_j exist and are unique if $Z_j(q_j)$ are rigorously convex (strictly increasing, i.e., expansion of q_j is accompanied by an increase in the production costs $Z_j(q_j)$). However, these same properties of the local cost functions are indispensable for the equivalence of global problems (3) and (6). In addition, if the possible sets of values for q_j in Eqs. (3) and (6) are convex, the

global criterion E is rigorously concave, and Z is a rigorously convex function, since they are non-negative linear combinations of the rigorously concave functions $E_j(q_j)$ and the rigorously convex functions $Z_j(q_j)$ respectively. Thus, the optimum solutions to Eqs. (3) and (6) are unique [7, pp 296-297]. The optimum values of all q_j are identical in the two problems, since Eqs. (4) and (7) describe the characteristics of the same local maxima $E_j(q_j)$. Lack of rigorous convexity for $Z_j(q_j)$ does not mean that there are no optimum combinations of different types of technology, but the problems in Eqs. (3) and (6) are then nonequivalent and there is no local search for optimum q_j . Thus, if $Z_j(q_j)$ are linear, the minimum value of Z for a given Q_0 can be found by linear-programming methods. However, the formulation of the problem in Eq. (3) is in itself inadequate here: it is necessary to formulate n constraints for use of $n > 1$ technological methods. The change in the restriction on the output of the production process in question that occurs when one moves on to the form of the problem used in Eq. (6) alters the optimum solution (reducing the number of basic variables). A local search for the optimum values of q_j is impractical, since the profitability E_j is independent of the scope q_j of method application (in view of the ambiguous estimates obtained in linear-programming problems, the values of E_j equal zero for any q_j in all the methods employed).

It is readily seen that the sense of the economic effect E_j is the same in Eq. (8) as in Eq. (2). On the other hand, Eq. (8) has a considerably wider field of application: in addition to passive computation of the actual profit resulting from the manufacture of a new product, maximization of E_j can, in contrast to the inflexible formula in Eq. (1), show the most advantageous combinations of technological methods when the initial problem takes the form of a requirement for minimum production costs for any predetermined output and product composition. If the prerequisites for equivalence of problems of the types in Eqs. (3) and (6) were met in all production processes, Eq. (8) could be a general-purpose tool for local searches for the technical-economic solutions of greatest advantage for the economy. The excessive stress placed on the "complete-replaceability" hypothesis is due to the increasing acceptance in the economic literature [8, p 53] and in studies of space economics [5, pp 240-241] of criteria of the type of Eq. (8), if only in the form of Eq. (2).

In order for Eq. (8) always to yield the solutions most favorable for the economy, the following prerequisites must be met: rigorous convexity (at least in the vicinity of the optimum) for the cost functions $Z_j(q_j)$, a property that is, in general, quite realistic but requires careful checking in each specific case; an optimum (or nearly so) product price (or, equivalently, optimality of the "preset" output level Q_0); the same optimality condition for the prices used to measure the elements of the costs C_j and K_j , as well as the norm for E . It can scarcely be assumed with any degree of confidence that current pricing indices have these properties.

The above difficulties in application of the criterion in Eq. (8), which naturally affect not only the combining of technologies but also the determination of

total production output levels, make it necessary to turn to more "cautious" optimization approaches, of the type in Eq. (3). In the field of RENR, such approaches suppose that all types of information demand are predetermined in terms of volume and content (i.e., the problem of seeking the best information supply for the national economy and its individual areas does not arise). This is a product not only of the fact that the economic consequences of the practical utilization of different types of information (particularly satellite data) have not been studied to a satisfactory extent but also of the unreliability or complete lack of prices for informational materials. Moreover, the cost functions for production of satellite information are distinguished by significant nonconvexity, since the expenditures associated with the operation of satellite systems are virtually independent of the volume of information they produce. Typically, satellite information systems have the adjusted-cost structure $Z_{SI} = Z_{\text{spac}} + C_{\text{pro}} S_{\text{spac}}$, where Z_{spac} are the costs related to the use of spacecraft and the maintenance of a network of ground stations and C_{pro} are the costs of processing the satellite data expressed per square kilometer [1, p 155]. Conversely, the number of terrestrial RENR systems in the territory varies quite clearly with the size of the territory to be studied S_{tr} , so that the adjusted costs in these areas of RENR (including aerial photography) are usually found to be proportional to S_{tr} [1, pp 157-158]. Most probably, the actual character of the functions $Z_j(q_j)$ in the RENR field is more complex, but the optimization approach can also be useful when they are interpreted in an approximate manner.

On the basis of these considerations, we can propose, e.g., the following schema for the optimization of an RENR system (the problem consists in planning for minimum total adjusted costs, taking into account fixed costs in the space industry):

$$Z_{\text{int}} = \sum_{t=1}^T \sum_{i=1}^M P_i(F_{ij}, \delta_{ij,t} + C_{ij} S_{ij,t}) + \sum_{t=1}^T \sum_{j''=1}^N P_{tj''} C_{j''} S_{j''} \rightarrow \min \quad (9)$$

under the conditions

$$\sum_{i=1}^M b_{it} S_{it} + \sum_{j=1}^N b_{jt} S_{jt} \geq B_{it}, \quad i=1, \dots, \lambda_1, \quad t=1, \dots, T, \quad (10)$$

$$\sum_{i=1}^M r_{it} S_{it} + \sum_{j=1}^N r_{jt} S_{jt} \leq R_{it}, \quad i=\lambda_1+1, \dots, \lambda_2, \quad t=1, \dots, T$$

$$S_{ij,t} \geq 0, \quad i'=1, \dots, M, \quad t=1, \dots, T, \quad S_{j'',t} \geq 0, \quad j''=1, \dots, N, \quad t=1, \dots, T,$$

$$S_{ij,t} = \begin{cases} 0, & \text{if } S_{ij,t} < 0 \\ 1, & \text{if } S_{ij,t} > 0 \end{cases}$$

where T is the number of segments of the planning period (years), M is the number of types of information, N is the number of types of methods for gathering and delivering information, for example, systems utilizing natural-resources satellites, manned spacecraft, as well as systems utilizing ground-based facilities, with different parameters for the costs of production of information, P_i are the parameters of the cost functions for the production of information, $P_{tj''}$ are the parameters of the cost functions for the production of information, F_{ij} are the parameters of the cost functions for the production of information, $\delta_{ij,t}$ are the parameters of the cost functions for the production of information, C_{ij} are the parameters of the cost functions for the production of information, $C_{j''}$ are the parameters of the cost functions for the production of information, b_{it} are the parameters of the cost functions for the production of information, b_{jt} are the parameters of the cost functions for the production of information, r_{it} are the parameters of the cost functions for the production of information, r_{jt} are the parameters of the cost functions for the production of information, B_{it} are the parameters of the cost functions for the production of information, R_{it} are the parameters of the cost functions for the production of information, $S_{ij,t}$ are the parameters of the cost functions for the production of information, $S_{j'',t}$ are the parameters of the cost functions for the production of information.

with the conditions

$$\sum_{j=1}^{M+N} \sum_{k=1}^{V_j} B_{ij}^k \delta_j^k > B_{it}, \quad i=1, \dots, \lambda_1, \quad t=1, \dots, T, \quad (15)$$

$$\sum_{j=1}^{M+N} \sum_{k=1}^{V_j} R_{ij}^k \delta_j^k < R_{it}, \quad i=\lambda_1+1, \dots, \lambda_2, \quad t=1, \dots, T, \quad (16)$$

$$\sum_{k=1}^{V_j} \delta_j^k \leq 1, \quad j=1, \dots, M+N, \quad k=1, \dots, V_j, \quad (17)$$

$$\delta_j^k = 0, \quad \text{or } 1, \quad j=1, \dots, M+N, \quad k=1, \dots, V_j. \quad (18)$$

Here the search for the optimum utilization scales for RENR methods is carried out not directly but on the basis of preliminary potential "development plans," which provide a set of alternative degrees of utilization (with subscripts $k = 1, \dots, V_j$) for each method j in all years of the planning period. The only unknowns in Eqs. (14)-(18) are the integral variables δ_j^k , each of which expresses adoption or rejection of one of the potential development plans for the corresponding information system (space-based methods are not singled out here, since fixed costs are automatically included or excluded when a potential development plan is adopted or rejected). The predetermined parameters $Z_{jt}^k = C_{jt} S_{jt}^k$, $B_{ijt}^k = b_{ij} S_{jt}^k$, and $R_{ijt}^k = r_{ij} S_{jt}^k$ are not specific but general. Solution of Eqs. (14)-(18) ensures balancing of RENR development programs with respect to demand and resources, as well as selection of the set of information-system development plans with minimum costs from among the potential plans preliminarily compiled. The fundamental weakness of this approach is the fact that one cannot be certain that the solutions chosen in Eqs. (14)-(18) will be identical (or similar) to those which would be found in a direct search for the optimum degrees of utilization of RENR methods with the model in Eqs. (9)-(13); for this to be the case, they must be included among the plans preliminarily compiled.

One of the basic defects in current economic calculations for space technology is the unsatisfactory reflection of the economic role of the time factor. The increasingly common distrust of the discounting of costs and effects also contributes: the "true" gages of real economic parameters are often merely nominal indices of estimated value, current expenditures, etc., while the adjustment factors employed are artificial speculative constructs. In actuality, it is naturally adjusted parameters that provide the yardsticks of real economic results and costs, since localization in time is one of the important useful properties of products and resources. The proposal that adjustment factors be converted from purely formal computational indices (the role they play in methods based on effectiveness) to cost-accounting categories that have real applications, affecting the disposition of capital appropriations, calculations pertaining to the services rendered to clients by construction and installation organizations, etc. [10, pp 187-190], therefore seems to us to be proper and a matter of some urgency.

However, the adjusted parameters employed in current calculations for the effectiveness of RENR are almost exclusively in the form of adjusted annual costs and effects. This approach is quite justified within the framework of the method described in the reference literature [6], which is essentially a set of economic rules for replacement of equipment and is characterized by operating-cost and productivity indices that remain virtually constant with time. However, the goals of RENR, i.e., the development with time of complex information systems serving many areas of the national economy, are far broader. Instead of regular series of current expenditures and output levels following initial investments for the construction and installation of equipment, we are here dealing with construction and production programs in which different facilities are put into operation (or decommissioned) during different segments of the planning period, output levels vary widely with time, and capital investments are generally made over the entire period of operation, simultaneously with product output.

Analysis of such situations requires calculation of the integral costs and effects, as was convincingly shown by Kantorovich et al. [11]. These authors also provided justification for the assertion that, in the general case, integral indices serve as the initial parameters and adjusted annual figures can be derived from them when a number of rigorous technical-economic conditions are observed (these essentially describe individual equipment units, production subfacilities, and similar local facilities with fixed productivity levels). In our opinion, the general formula for the integral "absolute" effect [11, p 817], which can be written in the form*

$$E_{\text{int}} = \sum_{i=1}^T (p_i q_i - C_i - K_i) (1+E)^{t-i}, \quad (19)$$

where τ is the date of adjustment, should be recommended as the basis for all methods for making cost-effectiveness calculations. It would be best to append a description of situations that justify use of given variants of Eq. (19) and permit a reduction in the number of calculations required. Comparing the value of E_{int} with zero (the character of the relationship depends on the aforementioned properties of the cost functions, i.e., convexity or nonconvexity), in conformity with the above study [11, p 818], and utilizing different hypotheses regarding the dynamics of the components of E_{int} , persons engaged in the development of technical-economic variants could select the modification of Eq. (19) most appropriate to the case at hand. Thus, with the conditions $p_t q_t = pq$, $C_t = C$, $K_{t=\tau} > 0$, and $T = \infty$, one obtains the usual formulas for annual costs, in the form $C + EK$; in the case of capital expenditures over the entire period T , where $T < \infty$, we obtain the adjusted annual costs in the form

$$C + (\alpha + E) \sum_{i=1}^T K_i (1+E)^{t-i}, \quad (20)$$

where α is the amortization norm with time taken into account, as recommended in

*Here and in Eq. (20) below, it is assumed that system operation is discontinued when $t > T$ (there is no "aftereffect"). If this were not the case, the annual capital investments K_t would have to be replaced with lease-cost estimates for the production inventories included in the system.

Table 3

Landsat-Type System (Two Satellites), Millions of Dollars per Year

Index	Year												
	1	2	3	4	5	6	7	8	9	10	11	12	Total
Capital investments (1)	13.8	57.3	50.9	21.4	14.8	2.0	41.8	35.6	16.4		12.8		
Operating expenses (2)	0.7	2.5	4.6	6.5	6.3	5.9	6.2	5.6	6.3	5.9	6.2	5.5	333.1
Total of (1) + (2)	14.5	59.8	55.5	27.9	21.1	7.9	48.0	42.2	22.7	5.9	19.0	5.6	
Adjusted costs: (1) + (2)	16.0	59.8	50.4	23.0	15.8	5.2	29.8	23.8	11.6	2.8	8.1	2.2	248.5
$\tau=2, E=0.10$													

the literature [6]. It is precisely the lack of generally accepted rules for relating integral and annual costs that probably accounts for the occurrence in publications on RENR of curious formulas, such as that for the "annual cost of producing satellite information"

$$\sum_{i=1}^T C_i (1+E_{np})^{i-1} (1+E_n K),$$

which are usually proposed without any derivations or indications of preconditions given [5, p 242].

Other important assumptions [11, p 820] are that it is improper to use annual indices if the technical-economic prerequisites for convergence of the integral and annual parameters are not met and that direct use must be made of integral formulas of the type of Eq. (19) in such cases. The data given in Table 3 on the characteristic dynamics of annual costs in satellite information systems [4, p 23] make it possible to evaluate the extent to which these prerequisites are likely to be met.

Such substantial variations in annual costs (by factors of more than 10 for unadjusted indices and 20 for adjusted indices) are due to material factors, i.e., the short service lives of AES and the periodic updating of the "space fleet." In view of the relative stability of annual operating costs, it might be possible to make some use of simplified formulas of the type of Eq. (20). However, still another method is used in practice: instead of checking the convergence conditions for the integral and annual parameters, a given year of operation is chosen as the "standard" year. On the other hand, years with high costs are as typical of satellite information systems as years with low costs; economically justified decisions are scarcely possible if integral parameters are not taken into consideration.

The improvement of economic substantiation methods for RENR is presently being impeded by a number of factors, of which we feel the most important to be: 1) the fact that the economic consequences of the use of satellite information systems and traditional RENR methods in various areas of the economy have not been satisfactorily studied, which hampers determination and maximization of the economic effect of RENR systems; 2) the lack of sufficiently clear concepts regarding the character of the functional technical-economic relationships between costs and results, which makes it difficult to select the appropriate types of mathematical models for adequate description of economic situations and for optimization calculations; 3) the imperfection of

pricing systems, which prevents use of economic criteria of the type of Eq. (8) with any degree of confidence.

While solution of the latter problem has a general economic character, hopeful advances relating to individual sectors of the economy are being made in work on the first two problems. Many organizations involved in RENR, not being satisfied with the restricted framework provided by calculations made with Eq. (1), are conducting interesting investigations with an effect on the industrial activity of different economic sectors through progress in the provision of information. On this basis, they are also raising the question (albeit in general form) of ways to meet the need for joint optimization of information processing and utilization processes. In addition, a number of organizations are making studies (as yet purely technical) to establish the overall "information productivity" of satellite information systems as a function of a number of information characteristics (resolving power, periodicity of observations, rate of information delivery, size of bands covered by satellite sensors, and total territorial coverage) dictated by the technical system-implementation variant chosen. We can quite confidently conclude that, in general, there is a tendency toward information saturation, i.e., that the total information productivity of a system is a concave function of the improvement in system parameters. This conclusion is justifiably considered to be important for optimization of satellite information systems. It would seem that this "engineering-technical" relationship can (and ultimately should) be translated into the language of economic results and costs for the entire set of operations involved in the processing and commercial utilization of satellite information; this will provide a suitable basis for the use of optimization models (i.e., convex programming) with adequate analytic and computational capabilities.

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PURPOSE, BACKGROUND OF 'INTERCOSMOS-21' MISSION

MOSCOW ZEMLYA I VSELENNAYA in Russian No 5, Sep-Oct 81 pp 39-41

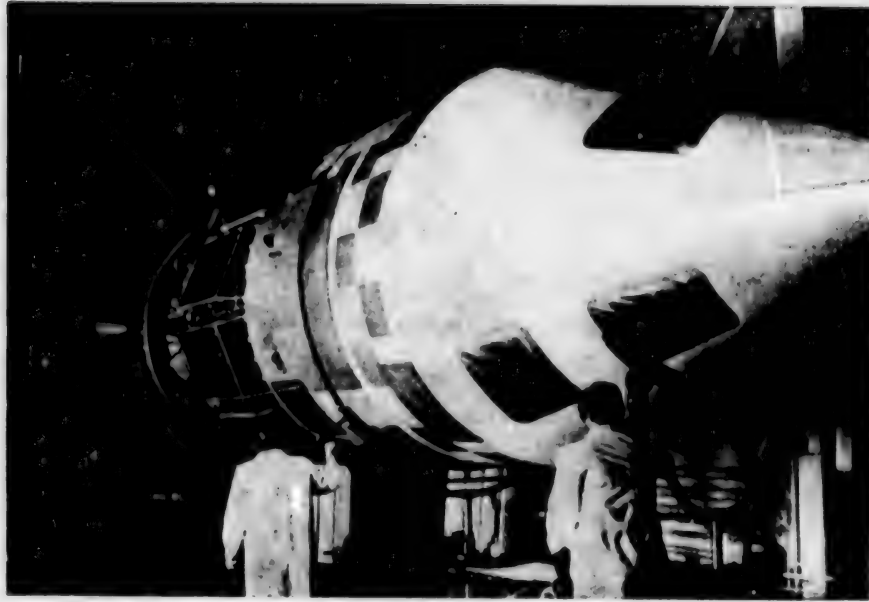
[Article by M.A. Rimsha]

[Text] On 6 February 1981, the "Interkosmos-21" artificial Earth satellite was launched successfully in the Soviet Union. During its flight an information collection and transmission system operating over a unique bridge--Earth-satellite-Earth--was tested.

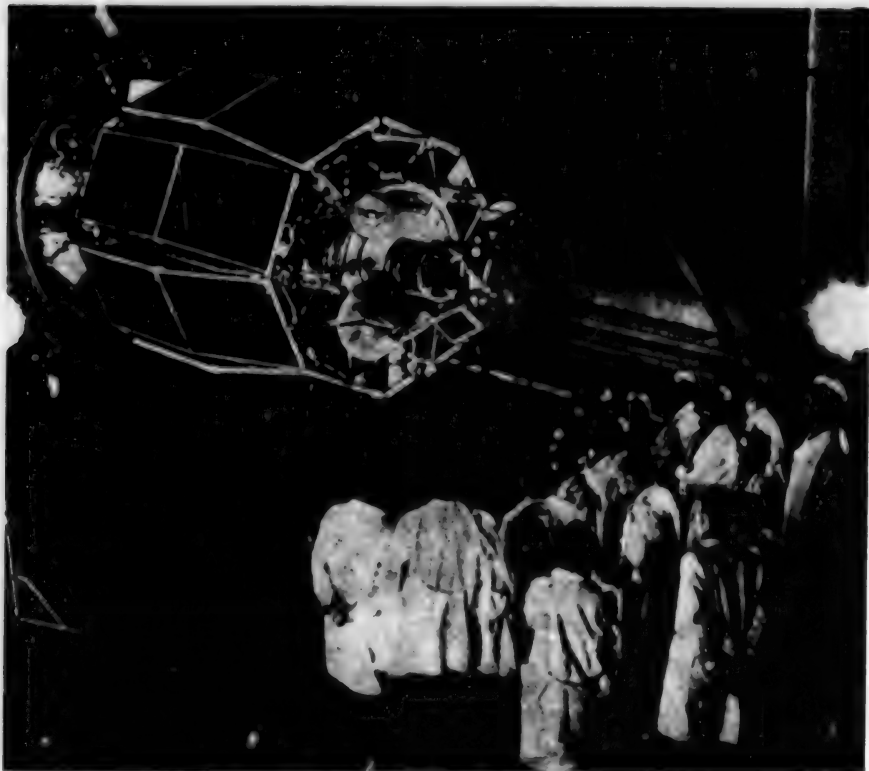
The subject matter of the research performed with satellites of the "Interkosmos" series is constantly being expanded. Scientists have investigated short-wave emissions of the Sun and the Earth's ionosphere and magnetosphere, cosmic rays and meteorite flows. Various technical systems have been tested in these satellites and introduced into the program of joint scientific research. A transmitter of the "Beacon" type operated successfully in the first "Interkosmos" satellites, while a special telemetric system later functioned in space and was recommended for further use (ZEMLYA I VSELENNAYA, No 1, 1980, pp 44-47). The Unified Telemetric System, with the help of which scientific information from on-board instruments began to be transmitted directly to ground stations without the use of the spacecraft's own service systems, underwent flight testing on board the "Interkosmos-15" (ZEMLYA I VSELENNAYA, No 3, 1978, pp 48-49). Specialists from the Hungarian People's Republic, the GDR, the Polish People's Republic, the USSR and the Czechoslovakian SSR took part in the creation of this system. It is now used in almost all "Interkosmos" satellites.

Having successfully completed their work on the telemetric system, its inventors then turned to the solution of a new scientific and technical problem. The "Interkosmos-21" satellite became the testing laboratory for an information collection and transmission system (SSPI) that was developed and manufactured in the Hungarian People's Republic, the GDR, the USSR and the Czechoslovakian SSR. The goal of the experiment was an integrated study of the world ocean and the Earth's surface and the automatic collection of scientific information from ground platforms and marine buoys, with subsequent transmission of it to ground stations.

The SSPI consists of two parts, one of which is in the satellite and one of which is on the ground. The eight instruments of the on-board SSPI complex were installed in the "Interkosmos-21" satellite. The system's ground receiving and transmitting equipment was placed in special buoys and on special platforms that were placed in the water and land areas, respectively, that were to be investigated.



Preparations for the flight of the rocket that carried the "Intercosmos-21" satellite into orbit.



The "Intercosmos-21" artificial Earth satellite and its creators.

The buoys and the platforms are automatic research laboratories. In addition to the instruments belonging to the ground part of the SSPI, they are "stuffed" with various sensors that measure the different parameters that are characteristic of a given region and equipment that records the readings in memory units, the capacity of which makes it possible to accumulate information over a number of days.

During the flight the satellite, which is equipped with the on-board SSPI complex, sends interrogative signals to Earth constantly and "calls up" the subscribers (as we will henceforth call the buoys and platforms) that lie along its path. Upon receiving a signal from the satellite, the subscriber analyzes its "reliability" and eliminates the possibility that it has received a randomly generated spurious radio signal. Having determined that the signal is from its "own" satellite, the subscriber turns on its transmitter and sends an answering signal to the SSPI's on-board receivers, thereby confirming that the buoy or platform is ready to operate. Now it is the satellite's turn to analyze whether or not the signal is from the proper subscriber and to evaluate its quality from the viewpoint of the interference and noise level. When there is a positive answer to these questions, the SSPI's satellite complex sends a signal that turns on the subscriber's transmitters, which send the scientific information that has been accumulated for a number of days to the satellite. The transmission process takes 20 seconds, and the information is then recorded on tape in the satellite.

During the communication session the satellite transmits to the subscriber the measurement program for the next few days.

The satellite conducts the same "logic dialog" with every subscriber over which it passes at a given time during its flight. When it passes over the ground receiving stations it transmits to Earth all the information it has gathered from the buoys and platforms. In addition to this, the SSPI can also operate in a "direct transmission" mode by immediately retransmitting the information received from its subscribers to whatever ground receiving station is in the satellite's radio visibility zone at that time.

The creation of an automatic Earth-satellite-Earth communication link makes it possible to investigate large areas on the surface of our planet, particularly--and this is extremely important--in areas that are difficult to reach and where it is now impossible to organize constant observations and investigations in which man takes part.

On its present flight, which is of an investigative nature, the on-board part of the SSPI has been working with subscribers located in the Hungarian People's Republic, the GDR and the USSR. When the system's capabilities are fully utilized, it can handle a terrestrial network of 256 buoys and platforms.

What scientific problems will be assigned to the SSPI in the future? The data obtained by this system will make it possible to achieve a significant increase in

our knowledge about the world ocean, the natural phenomena and processes that are related to it, and the riches present in its waters and on the continental shelves. In particular, we expect to produce better maps of the ocean's shore line and the ice fields in it. Meteorologists will have the capability of detecting dangerous storm and hurricane regions with the help of the SSPI. This information will obviously be of great help to ship navigators and will insure the safety of seafarers. Fishermen will be able to utilize operational data on the possible location of fish.

The problem of protecting the purity of ocean waters and the coastal zone is an extremely urgent problem at present. The solution to this problem is also within the SSPI's sphere of activity.

A multichannel spectrophotometer, which was built in the GDR and installed in the "Intercosmos-21," measures the atmosphere's optical parameters in different bands of the spectrum, while a magnetometer of joint Soviet-Rumanian origin is used to investigate the spatiotemporal distribution of the Earth's geomagnetic field's rotation.

The scientific equipment on board the satellite also includes a Soviet bipolarized radiometer that is used to measure the intensity of the radiothermal emissions of the system formed by the atmosphere and the underlying surface. With its help, oceanological scientists are obtaining information on the thermodynamic temperature of the ocean's surface.

During the years the "Intercosmos" program has been in existence, permanent creative collectives of scientists and specialists working in the field of space research have been organized in many fraternal countries. Their high scientific potential and professional expertise are helping to solve many complicated problems. There are many of these collectives that are veterans of the collaborative efforts that led to the creation of the "Intercosmos-21."

Scientists and specialists from the Electronics Institute (now the Institute of Space Research) of the GDR's Academy of Sciences, in Berlin, played an active part in the preparation of the first satellite launched in the "Intercosmos" program, in October 1969. At that time only a small group of workers at the institute were engaged in work on subjects related to space. Their successful "space debut" served as a good springboard for the further development of their activities. At the present time this group has become a powerful scientific collective. A significant part of the work on the creation of the SSPI was performed by workers from this institute. They also built the multichannel photospectrometer. The GDR Academy of Sciences' Dresden Polytechnic University also participated in the preparation of the equipment for the "Intercosmos-21" satellite.

The on-board power sources for many of the "Intercosmos" satellites were manufactured at the Budapest Polytechnic University. The first experiment conducted by Hungarian specialists, on the "Intercosmos-17," was successful. After that, equipment from the Hungarian People's Republic acquitted itself successfully as part of the Unified Telemetric System, and now new tests are being carried out.

The Czechoslovakian "Tesla" production association also participated in the creation of the SSPI. Its representatives are constantly developing instruments for use in the "Intercosmos" program.

On the Soviet side, the planners of the SSPI project are the Ukrainian SSR Academy of Sciences' Marine Hydrophysical Institute and the USSR Academy of Sciences' Institute of Space Research, which are invariable participants in almost all international satellite experiments. Workers from the USSR Academy of Sciences' Radio-electronics and Oceanographic Institutes helped build the scientific equipment for the "Intercosmos-21."

The experiment on measuring the Earth's magnetic field was prepared jointly by specialists from the Romanian Socialist Republic Academy of Sciences' Central Institute of Physics and Technology, in Bucharest, and the USSR Academy of Sciences' Institute of Terrestrial Magnetism, the Ionosphere and Radio Wave Propagation.

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'INTERSPUTNIK' COMMUNICATIONS SYSTEMS

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 10, Oct 81 pp 40-41

[Article by V. Romantsov: "'Intersputnik' Orbits"]

[Text] Radiocommunications in space occupies an important position both in our country's national economy and in international communications. Ever-increasing demands with respect to exchange of information and the high degree of operational effectiveness our sputniks possess for effecting this have led to the creation of a great number of national and international communications systems. In the Soviet Union these encompass the "Molniya," "Raduga," "Gorizont" and "Ekran" television broadcasting and communications systems--already well known. International space communications systems "Intersputnik," "Intelsat," "Eurosat," "Afrosat," and others have come into operation or are being designed.

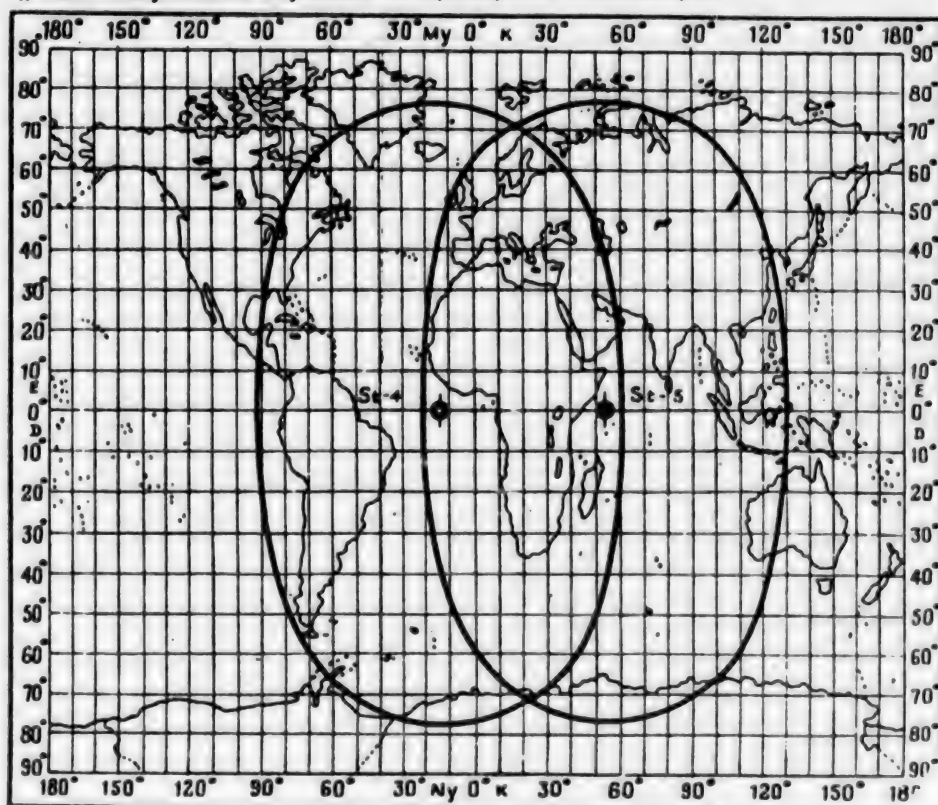
November 15th will mark the tenth anniversary of signing of the "Agreement on the Creation of an International System and the Organization of 'Intersputnik' Space Communications," original participants to which are Bulgaria, Hungary, GDR, Cuba, Mongolia, Poland, Romania, USSR and Czechoslovakia. Afghanistan, Vietnam and South Yemen joined later.

The legal and technical bases for "Intersputnik" were developed within the framework of cooperation among the socialist countries in the sphere of conquering and using outer space for peaceful purposes in the "Interkosmos" program. Its activities are based on respect of sovereignty, non-interference in internal affairs, and mutual assistance, mutual benefit. "Interkosmos" is an open inter-governmental organization in which any state may become a member that recognizes its aims and principles of activity, and undertakes the obligations which ensue from the agreement. Its ruling body is the Council, composed of one individual per member nation. The executive and administrative body is the Directorate.

The "Intersputnik" system of communications consists of a space complex and earth stations. Under lease agreements, Soviet artificial earth satellites of the "Statsionar" type are used. They are located on a geocentric, circular orbit at points 14 degrees west longitude (Atlantic region) and 53 degrees east longitude (Indian region). The orbit lies in the plane of the equator at an altitude of about 36,000 km from the earth's surface. Here the sputniks rotate with the same angular velocity as does our planet. They are therefore stationary with respect to any point on it. Each sputnik can be compared to a giant relay-transmitter tower whose zone of service extends 130 degrees in longitude and 165 degrees in latitude.

Three sputniks positioned in geostationary orbit at a distance of 120 degrees from one another can provide transmission of information between earth stations over almost the entire territory of the globe (excluding the polar regions). In a word, they allow us to create a kind of space information "bridge" between cities, countries and continents separated by vast distances. They encounter no sea or ocean interference; there are no forests or deserts, no mountains or other natural barriers to create the significant difficulties that occur from time to time in constructing ground-based communications links. Thus, the zone of service for the "Statsionar-4" sputnik encompasses the eastern portion of North and South America, Europe, Africa, and regions of the Middle and Near East. "Statsionar-5" covers Europe, Africa, parts of the Middle and Near East, a large portion of Asia and the western half of Australia. Of course, either of these satellites can service the central parts of these zones. Communications between nations whose territory can be seen by only one of the sputniks is possible through an earth relay station located in the central zone using a double-satellite jump, or a single jump and ground-based communications links.

★ Зоны обслуживания спутников «Стационар-4» и «Стационар-5».



Twelve earth stations operate in the "Intersputnik" system. Seven are in Europe (Bulgaria, Hungary, GDR, Poland, two in USSR, Czechoslovakia), three are in Asia (Afghanistan, Mongolia, Vietnam); one is in Central America (Cuba) and one is in North Africa (Algeria).

The earth stations are equipped so as to provide for simultaneous, round-the-clock operation in both the television and telephone channels of the "Statsionar" sputniks. The television channel equipment allows for reception and transmission in black-and-white or color, and uses two sound-tracking circuits that can also be used for transmitting radio broadcasts.

The telephone channel equipment provides duplex telephone circuits and secondary multiplexing for telegraph, phototelegraph and telecode information signals. Multi-station access is applied for telephone communications using frequency separation for signals emanating from the earth stations. All stations can operate simultaneously using a single relay station without mutual interference. They transmit and receive telephone communications signals in the frequency bands designated for them.

The earth station has a parabolic mirror 12 meters in diameter, an irradiation system, a waveguide transmission system, and antenna-to-sputnik guidance equipment. Auxiliary communication equipment enables the earth stations to communicate operationally with one another. The quality indices for transmission of all types of information meet international standards.

The "Intersputnik" space communications system has allowed its participants to set up direct contact with each other using the technical means established within the framework of the socialist community.

Other interested consumers use the system's channels as well. More than 20 countries are participating in television program exchange. About as many are using the system's channels for telephone and telegraph links. Television broadcasting is conducted from four to eight hours daily.

Member nations of "Intervideniye" implement an exchange of about 40 percent of their television programs through the "Intersputnik" system. These programs provide information on important political, cultural, sports and other events in the world. It is in this way that broadcasts of the Olympic games in Moscow were received by more than 30 countries in Europe, Asia, Africa and Latin America. There were 460 broadcasts conducted, 820 hours in total duration. A great volume of broadcasting was conducted from the 26th CPSU Congress, and from party congresses of the fraternal socialist countries, as well as flight coverage of international space crew missions.

Earth stations will receive new and more sophisticated radiotechnical equipment in the future. This will provide for greater operational efficiency in the use of the "Statsionar" sputnik channels, increased circuit quality, and greater functional reliability in system operation.

The activities of "Intersputnik" underscore the high degree of effectiveness in using outer space for peaceful purposes. They further the strengthening of cooperation among countries and facilitate the broadening of international information exchange. Documents of the 26th CPSU Congress cite the peaceful conquest of space as one of the international issues with which the Soviet Union will be actively engaged.

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SATELLITES AND RADIONAVIGATION

Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 11, Nov 81 pp 40-41

[Article by I. Meshcheryakov, S. Sil'vestrov and A. Tsepelev, doctors of technical sciences]

[Text] A precipitous increase in speed and a considerable expansion of service areas are characteristic features of modern transportation systems. Air and ocean routes traverse vast areas and cover the entire planet, including the Arctic and Antarctic. As a consequence, new requirements are being imposed on navigation. The position of aircraft and ocean liners must be determined on a global scale, continuously, rapidly, and with high accuracy.

For hundreds and even thousands of years, mariners were guided by the stars, Sun, and other heavenly bodies. Maritime navigation had its origin in remote antiquity. Extremely simple methods for navigating ships were known not only to the Egyptians and Phoenicians, but also to peoples at a lower level of development. The foundations of modern navigation were laid by the use of the magnetic compass to determine the course of ships, by maps drawn on the right isogonal cylindrical projection, and by the mechanical log. Advances in physics made it possible to develop electronic navigation instruments and radionavigation systems.

The principles of aerial navigation derive from maritime navigation. There is no need to examine them in detail, since the reader versed in aviation is thoroughly familiar with the technical devices and methods employed for determination of navigational elements (heading, drift, ground bearing, air and ground speeds, altitude, and aircraft position coordinates). We need only note that each group of technical devices has its own advantages and drawbacks. Thus, techniques that utilize observation of astronomical reference points by means of optical instruments are dependent on visibility conditions, i.e., weather and time of day. This naturally has a detrimental effect on the ability to obtain the requisite data rapidly. Navigation methods utilizing terrestrial systems do not permit coverage of all the necessary territories, since it is impossible to install radio beacons everywhere. Moreover, such methods do not always have the required precision. As for inertial systems, their accuracy deteriorates in direct proportion to the time since the last navigation fix. Frequent correction on the basis of data obtained from other systems is therefore required.

It is possible substantially to increase the efficiency of navigational services and give them the requisite properties with respect to global coverage, rapidity, and accuracy by creating space-based navigation systems in which artificial earth satellites serve as reference points. Here it is best to employ the UHF range, in which it is possible to use devices that permit highly accurate determination of the distance, rate of change in distance, and direction to a satellite. Gathering of the requisite data rapidly is achieved by simultaneous observation of several satellites. If they can be observed at any point in near-earth space, the problem of providing a global navigation service is solved. There is another circumstance of great importance. The structure of a satellite radionavigation system is selected in such fashion that any number of aircraft and ships can simultaneously and independently determine their positions.

A major role in a satellite navigation system (Fig. 1) is played by command-measurement systems. Ground stations make measurements of the satellite trajectories. The resultant data are transmitted through communications channels to a computer center, where orbital parameters and various corrections (e.g., the time-base deviation of the on-board clock) are determined and predicted. The orbital parameters at each instant for which a prediction is made are customarily referred to as the satellite ephemerides. The corrections and ephemerides go through communications channels to the command-transmission station, which sends them to the satellite at definite intervals. They are recorded in the satellite memory unit. The satellite continuously transmits radio signals and its ephemerides in real time. The ephemerides and time signals are received on Earth by radio and the navigational parameters are simultaneously measured. The information obtained is utilized by a computer to calculate the location of the aircraft or ship.

The coordinates and velocity of the satellite must therefore be continuously known. What navigational parameters must be measured? The answer to this question is unambiguous: only those that are mathematically related to the coordinates of the aircraft's position. This mathematical relationship is termed the equation of navigation. It is simplest to measure the oblique distance from the aircraft to the satellite and the radial speed, i.e., the rate of change in this distance. The former is proportional to the signal delay time and the latter to the Doppler frequency. Modern radio systems permit determination of the distance to within a few meters and of the radial speed to within a few millimeters per second.

In order to establish the position of an aircraft or ship, it is necessary to know three coordinates (x , y , and z). The minimum number of measurements of the oblique distance is therefore three (e.g., the distances to three satellites). A system of three equations of navigation in three unknowns must consequently be solved. The scope of the present article does not permit detailed examination of this problem. We might merely note that it can be successfully solved by the on-board computer, using a predetermined algorithm. We will limit ourselves to a graphic geometric illustration of this so-called distance-measurement method for taking navigational fixes (Fig. 2).

Let us assume that the distance to the first satellite has been measured with an aircraft's radio system. We can visualize a sphere with the satellite at its center. Its radius equals the distance to be measured. Where is the aircraft located? Obviously at the center of the sphere. If the distance to the second satellite is

measured at the same time, it is quite apparent that the aircraft should be simultaneously located at the surface of a second sphere (with its radius and center determined by the distance to the second satellite and its position) and hence on the line representing the intersection of the two spheres. Having determined the distance to a third satellite, we obtain not a line but the two points at which the three spheres intersect. At which of these is the aircraft located? This question can be answered on the basis of approximate information regarding the aircraft's position.

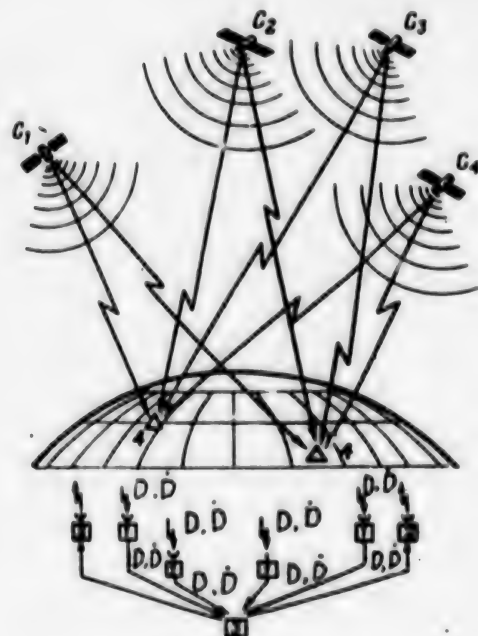


Fig. 1. Diagram of satellite navigation system. C_1, C_2, C_3, C_4) Satellites; 1) CMS measuring instruments; 2) transmission station for ephemerides; 3) computer center; 4) users; D) distance; $\dot{D}$) radial speed.

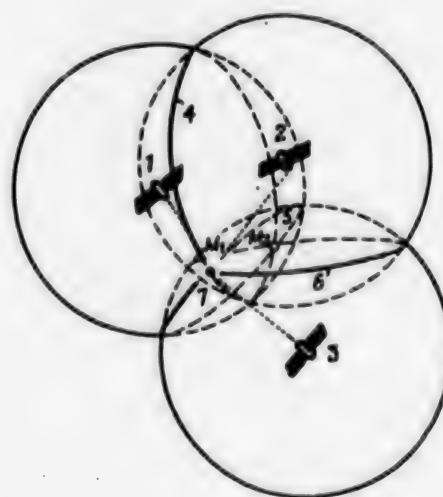


Fig. 2. Distance-measurement method for navigation fixes. 1, 2, 3) Satellites; 4, 5, 6) lines of intersection for spheres with radii equal to distances to vehicle being navigated (aircraft) 7; M_1 and M_2) intersection points of spherical surfaces.

It should be noted that, under actual conditions, one is dealing not with two points but with two spherical triangles, whose dimensions characterize the accuracy of the navigational measurements or the relationships employed. How can the dimensions of the triangles be reduced? This can be done by taking into account the factors that affect the errors in the measurements and calculations. Correct choices must be made of the optimum set of satellite orbits, the number of satellites and their relative positions in their orbits, and the elevation angles at the time of the fixes, consideration must be given to radio-wave propagation conditions and the non-synchronicity of the on-board clock, and the best data-processing methods must be

selected. methodological and instrumental errors include inaccuracies in our knowledge of atmospheric parameters, light pressure, and the constants characterizing the Earth's gravitational field, its geodesic coordinates, the displacement of the poles from the Earth's axis of rotation, the nonuniformity of its rotation, and a number of other factors related to determination of the satellite ephemerides, as well as errors in measurement of the navigational parameters and in the standard time service. Accumulation of these errors is avoided by periodic updating of the ephemerides and verification of the standard-time clock. The latter operation is carried out once or twice a day for the Soviet Tsikada system and every 12 hours for the American Transit system.

In the radial-velocity method, the navigational parameter to be measured is the radial velocity. The equation of navigation has a more complex form in this case. We can also give a graphic geometric illustration of the use of this technique. The only difference lies in the fact that the points sought lie at the intersection not of spheres but at the surfaces of three right circular cones.

A composite method can be employed to determine the coordinates of a craft's position and its speed in real time. Simultaneous measurements of the distances to three satellites and the radial velocities with respect to them are used to find the three coordinates of the craft's position and the three components of its speed vector at the time when the measurements are made. Six equations of navigation (three for distance and three for radial velocity) are compiled for solution of the problem. The equation system is solved with a computer.

Should the on-board radio equipment operate under an active or passive regime? Measurement of distance and radial velocity under the "question-response" regime entails a number of difficulties. Measurement of the distances between a single satellite and many users at the same instant not only requires more complicated equipment but imposes serious constraints on free access to navigational information. Under the signal-reception (passive) regime, navigational determinations made by different users are completely independent and the satellite radionavigation system can serve large numbers of aircraft and ships. Precise measurement of distance requires that there be no discrepancy between the time bases of the satellite clock and the users' chronometers. This is achieved by synchronization of the time bases of all navigational satellites with respect to the terrestrial standard used in the command-measurement system.

The equipment for a user operating under the passive regime consists of an antenna, receiver, computer, control system, and display. Navigational fixes are taken in the following manner. The system is tuned for reception of satellite radio signals. The data obtained are fed to the computer, which outputs the geographic coordinates of the craft. Communications can be in successive sessions during a single revolution or with several satellites simultaneously. The successive-measurement method is used in making calculations for stationary and slow-moving objects. The accuracy of coordinate determinations with the aid of the Tsikada system is 80-100 meters. Simultaneous observation of several satellites is more suitable for aircraft and ships. The navigational system is simpler in the first case, but a longer time is required for determination of position, since measurements must be adequately spaced in order to ensure the required accuracy.

The orbital altitude is also of considerable importance. The greater the altitude of a satellite, the larger is the angle covered by its field of view, so that fewer satellites are required. However, it is inexpedient to utilize an overly high orbit for a satellite on which successive observations are to be made, since this reduces the extent to which information can be gathered rapidly. Essentially, the angular velocity of a satellite increases as its altitude decreases, which means that successive measurements can be made more rapidly. Accuracy is also better in this case, since the angular differences between communications sessions are sufficiently large. This is why the Soviet Tsikada navigation system, which employs satellites of the Kosmos-1000 type, and the American Transit system employ nearly circular circumpolar orbits with altitudes of about 1000 kilometers.

Lower orbits are also disadvantageous. It is difficult to take into account the decelerative influence of the atmosphere on a satellite, so that the accuracy of navigational measurements is reduced. When several satellites are to be used simultaneously, their orbital altitudes should be 15-20 thousand kilometers. A further increase in altitude does not lead to any significant reduction in the number of satellites required and creates definite technical difficulties. The radio line-of-sight from the satellite to Earth becomes excessively long, making it necessary to utilize a larger power supply. The weight and cost of the receiving and transmitting equipment are also increased, producing a rise in launching costs. It is for this reason that it is considered unwise to use orbital altitudes above 20,000 kilometers. This altitude was selected for the American Navstar navigation system. Its 24 satellites are arrayed in three circular orbital planes with inclinations of 63° . No less than six satellites are visible from any points on the Earth's surface at a given time and three or four can be chosen for navigational measurements.

The accuracy of the satellite navigation system depends on the errors in determining the ephemerides, the synchronicity of the on-board clock, geometric factors characterizing the relative positions of the satellites, and the error in navigational measurements. Thus, a time-base discrepancy of one ten-millionth of a second results in an error of 50-100 meters in determination of the geographic coordinates of a craft. Generators with very high stability (a relative daily reference-frequency instability of the order of 10^{-14} - 10^{-15}) are needed. The time-base and frequency deviations of the on-board generators must also be taken into account.

The creation of a satellite system does not mean elimination of traditional navigation methods; it rather supplements them and gives them new features in terms of global coverage, continuity, accuracy, and reliability. It permits more efficient use of airspace. Pilots can take navigational fixes at any altitude en route and can obtain information on air-traffic density in the region of interest. In addition to improving flight safety, a satellite system permits more efficient airfield utilization (better organization of landing approaches and landings).

Satellite navigation systems will make it possible to obtain substantial savings for the maritime passenger fleet, an area in which there is significant potential. Economy measures include use of the best speeds and avoidance of the need to save time by travelling at high speed early in a voyage. The fuel savings for most liners can reach 4000-5000 tons per year. Fishing vessels can be aided in determining the exact coordinates of areas in which nets have been set out. Finally, the accuracy of manned-spacecraft navigation will be increased, particularly in approach and docking operations.

The creation of a satellite radionavigation system will mean great progress in navigation services for maritime commerce, aviation, and space flight, as well as in the solution of a number of other extremely important national-economic problems.

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APPLYING TECHNICAL DIAGNOSIS METHODS IN REMOTE SENSING OF DISTRIBUTED SPACE OBJECTS

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 257, No 3, Mar 81
(manuscript received 3 Oct 80) pp 553-558

PETROV, B. N., academician, BUGROVSKIY, V. V. and DUDIN, Ye. B.,
Institute of Control Problems and International Scientific Research
Institute of Control Problems

[Abstract] The use of computers for the processing of space information is limited by the still unsolved image recognition problem. Various man-computer methods in which most of the work on the interpretation and recognition of standard images is performed by man and the computer then applies these results to the entire image to be processed are highly promising. One of these methods is as follows. Visual information on the distributed space object to be studied, interpreted by specialists, is stored in a computer reference data bank; using these data, the computer analyzes the results of the current sensing session. The pertinent elements are registered by the computer and are then interpreted by the researcher. Such a method ensures adequate flexibility in operation of the man-computer system, although it imposes high requirements on the volume of the computer memory. At least a partial solution of this problem can be ensured by the technical diagnosis methods for the interpretation of visual space information using a computer. The essence of the proposed method is as follows. Available data are used in compiling a diagnostic table of criteria ("key") for the studied region. These are selected taking into account the specific image characteristics. These are primarily line, tonal and color characteristics of the diagnosed features. Further diagnostic work is accomplished using the computer. It is possible to use purely computer or man-computer procedures, the latter being preferable since purely computer diagnosis systems, without application of any image recognition methods, are applicable only in the simplest cases. Man-computer diagnostic procedures are promising with respect to both simplicity and results. The article describes two man-computer algorithms for application of the method: relative brightnesses algorithm and reference lines algorithm. The method is illustrated in two examples. In both cases the visual information

was obtained by space vehicles. However, in the first case (photograph of a sector of the Martian surface) there was no significant a priori information, whereas in the second case (photograph of a sector of the earth's surface) such information was available. In the first case it was possible to obtain significant information concerning Martian craters; in the second case it was possible to diagnose anthropogenic changes in the neighborhood of the Aral Sea. Figures 4; references: 6 Russian.
[152-5303]

UDC 528.711.7.029.672.001:553.63(285)

THERMAL SURVEYING IN CONNECTION WITH STUDIES OF KARA-BOGAZ-GOL GULF

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 4, Jul-Aug 81
(manuscript received 24 Nov 80) pp 11-17

GORNYY, V. I., Aerial Methods Laboratory, PGO "Aerogeologiya," Leningrad

[Abstract] Since Kara-Bogaz-Gol Gulf will soon be separated from the Caspian Sea, there is a great deal of interest in utilizing the salt deposits in it as chemical raw materials. The author investigates the use of thermal aerospace surveying to determine the composition of the gulf's salt cap, based on the different thermal properties of different salts. He reaches the following conclusions: 1) temperature contrasts that can be registered by television equipment installed in a space carrier arise in salt surfaces under favorable weather conditions; 2) aerospace thermal surveying, together with ground observations, can be an effective means for studying the gulf's hydrological regime and evaporation processes; 3) space thermal surveying can be used to observe seasonal changes in the salt bed's composition and structure; 4) space thermal surveying can be used to study salt migration as the salt bed is destroyed; 5) aerospace thermal surveying and other remote methods can be sources of the objective operational information needed to regulate the flow of water into the gulf as it is exploited industrially. Figures 4; references 8.
[9-11746]

DYNAMICS OF ARAL SEA BASIN ECOSYSTEMS AS DETERMINED FROM SPACE PHOTOGRAPHIC SURVEYING MATERIALS

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 4, Jul-Aug 81
(manuscript received 24 Dec 80) pp 18-26

SADOV, A. V., All-Union Scientific Research Institute of Hydrogeology and Engineering Geology, Moscow

[Abstract] The increasing aridity of the Aral Sea basin requires a thorough study of this region's ecosystems that can be accomplished either by having a dense network of stationary ground measurement points or by remote methods. The author investigates the utility of space methods in this process and reaches the following general conclusions: 1) the present state of the region's environment, with due consideration for the degree of disruption it has undergone, can be evaluated with the ehlp of space surveying; 2) the ecological background must be analyzed before indicative changes in it can be determined; 3) the rules governing both the natural and anthropogenic evolution of the environment can be traced by analyzing the structure of series of ecosystems seen in space photographs and the dynamics of changes occurring can be followed by using photographs taken at different times; 4) predictive maps of the region's evolution can be compiled on the basis of space photographs and a knowledge of future economic activities in the area. Figure 1; references 12.

[9-11746]

UDC 551.49:629.78

EXPERIMENT IN INFORMATION EVALUATION OF EFFECTIVENESS OF UTILIZING SPACE PHOTOGRAPHS IN HYDROGEOLOGICAL RESEARCH

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 4, Jul-Aug 81
(manuscript received 26 Dec 80) pp 27-31

BURLESHIN, M. I. and KOLOSKOVA, V. N., All-Union Scientific Research Institute of Hydrogeology and Engineering Geology, Moscow

[Abstract] The authors conduct a theoretical discussion of the quantitative aspect of space surveying information as applied to hydrogeological mapping and then use part of the northwestern Ustyurt Plateau as a concrete example. Their conclusions are: 1) space photographs are better than large-scale aerial photographs for studying hydrogeological conditions, since minor relief forms that do not affect those conditions do not appear in them; 2) when the underground water lies close to the surface, space surveying materials give a

great deal of information; when the water lies deeper, they can yield structural geological information; 3) hydrogeological maps compiled from space surveying materials are a new type of hydrogeological material for surface work such as planning canal routes; 4) the informational approach to the utilization of space surveying in hydrogeological research has several advantages: the evaluation of its effectiveness is closely related to the content of the hydrogeological map that is compiled and it provides an objective, quantitative basis for such maps. References 6.
[9-11746]

UDC 553.98:629.78

USING SPACE MATERIALS TO STUDY STRUCTURAL FEATURES OF CASPIAN GAS AND OIL PROVINCE

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 4, Jul-Aug 81
(manuscript received 19 Jan 81) pp 32-38

VOLCHEGURSKIY, L. F. and PRONIN, V. G., "Aerogeologiya" Geological Production Association, Moscow

[Abstract] The advent of the use of space photographs has contributed primarily tectonic information that is important in the interpretation of the earth's deep structure. As far as the Caspian gas and oil province is concerned, these photographs have confirmed its general boundaries, which are clearly identified with deep fractures covered by surface formations in which zones with an increased level of fracturing correspond to them, but have extended the boundaries in the eastern and southern parts of the region. They have also helped in the division of the province into different areas and regions and have led to the discovery of ring structures with diameters of up to more than 200 km within its boundaries. Figures 2; references 8.
[9-11746]

INTERRELATIONSHIP OF LINEAR AND ISOMETRIC OBJECTS IN SPACE PHOTOGRAPHS AND GAS- AND OIL-BEARING STRUCTURES OF BUZULUKSKAYA DEPRESSION

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 4, Jul-Aug 81
(manuscript received 26 Dec 80) pp 39-44

TROFIMOV, D. M. and DMITRIYEVA, B. I., Geology Department,
Moscow State University imeni M. V. Lomonosov

[Abstract] The Buzulukskaya depression, which lies mainly in the area bounded by Kuybyshev, Orenburg and Ural'sk, was chosen for the authors' study because of the exceptional clarity of the region's landscape features as viewed from space, the comparatively high level of geological knowledge about several levels of its vertical structure, and the large number of gas and oil deposits that have been discovered within its boundaries. By studying space photographs taken by the "Meteor-28" satellite (on a 1:5,000,000 scale) and from the "Salyut-4" orbital station, the authors conclude that the presence of gas and oil deposits is strongly correlated with the existence of linear structures but not circular ones. They recommend that space photographs with more detail be used as a basis for planning exploratory work. Figures 4; references 5.
[9-11746]

DETERMINING INTEGRAL PARAMETERS OF A CLOUDY ATMOSPHERE

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 4, Jul-Aug 81
(manuscript received 28 Nov 80) pp 61-65

SEMIN, A. G., TROKHIMOVSKIY, Yu. G., KHAPIN, Yu. B. and ETKIN, V. S.,
Institute of Space Research, USSR Academy of Sciences, Moscow

[Abstract] The authors present the results of numerical and full-scale experiments to determine the atmosphere's integral parameters (water vapor content and cloud moisture content and temperature) on the basis of radiothermal radiation measurements, made on board a laboratory aircraft, at wavelengths of 0.34, 0.8 and 1.5 cm. After setting up the mathematical apparatus, they use an iterational method to find the parameters. Their numerical experiment confirmed that an error in the apparent cloud temperature has little effect on the accuracy of the determination of water content when the three wavelengths mentioned above are used to make the measurements. The full-scale experiment was conducted from spring 1978 to December 1979, over the Caspian Sea, using

multichannel radiometers. The results were positive, with the apparent temperature, as determined from the measurements, being a consistent 4-5° less than the estimate of the temperature at the average cloud altitude. Figures 3; references 7.

[9-11746]

UDC 629.783:778.39

FEATURES OF INTEGRATION OF INSTRUMENTS WITH DIFFERENT VIEWING BANDS ON ARTIFICIAL EARTH SATELLITES

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 4, Jul-Aug 81
(manuscript received 14 Oct 80) pp 66-69

ASTASHKIN, A. A., SAUL'SKIY, V. K. and USPENSKIY, G. R.

[Abstract] Since it is impractical and unnecessary to build all space surveying instruments with viewing fields of the same width, the authors discuss the problem of calculating orbital parameters (altitude, inclination, period) that will provide unbroken coverage of the Earth's surface by all the instruments in a given complex. They conclude that the mathematical apparatus they have developed is suitable for this purpose and that when it is used, the satellite's orbital altitude must be maintained with a high degree of accuracy by use of low-thrust correcting engines. Figure 1; reference 1.

[9-11746]

UDC 528.71:518

INTEGRATED PROCESSING OF SPACE PHOTOGRAPHS AND GEOLOGICAL INTERPRETATION

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 4, Jul-Aug 81
(manuscript received 21 May 80) pp 70-75

YUDIN, V. S., Institute of Geology and Geophysics,
Siberian Department, USSR Academy of Sciences, Novosibirsk

[Abstract] The author advocates the processing and interpretation of space photographs in conjunction with the utilization of other information (gravimetric, magnetic, geochemical, and so on) in order to produce information that is as accurate as possible. This approach is needed to eliminate photographic anomalies caused by random factors. In addition it enhances the use of such photographs for prospecting for useful minerals. Figures 5; references 20.

[9-11746]

DIALOG SYSTEM FOR REGIONAL PREDICTION OF MINERAL RESOURCES FROM
GROUND AND SPACE SURVEYING DATA

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 4, Jul-Aug 81
(manuscript received 10 Jun 80) pp 76-82

CHUMACHENKO, B. A., MARCHENKO, V. V., VLASOV, Ye. P. NEMIROVSKIY, E. A. and
YAKOVLEV, V. A., International Scientific Research Institute of Control
Problems, Moscow

[Abstract] At present not enough specialized information is used in the machine processing and interpretation of space and ground geological surveying data. The authors describe a problem-oriented man-machine system for the solution of geological prediction problems that satisfies the following conditions: 1) combines organically the information gathering, storage and processing capabilities of modern computers and the theoretical and practical knowledge of specialists; 2) consists of a territorial geological data bank, an alternative solution development unit, a dialog procedure unit, and man-machine interaction encompassing all stages of the solution of predictive problems; 3) gives specialists the capability of making multivariant predictions on the basis of different approaches and analyzing the final results. They then describe in detail the operation of the "Region" regional forecasting system which was developed to satisfy the above conditions. Figures 3; references 5.

[9-11746]

UDC 551.508.85:621.396.96

DIGITAL PROCESSING OF RADIO SIGNALS REFLECTED FROM EARTH'S SURFACE

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 4, Jul-Aug 81
(manuscript received 21 Nov 80) pp 83-90

ONOPRIYENKO, Ye. I.

[Abstract] The author discusses techniques and special features of the digital processing of reflected radio signals, as applied to measurements of the back-scattering diagram in the vicinity of the normal to the surface ($+30^\circ$). After giving the initial relationships and formulating the problem, he develops general processing algorithms and describes a system of instruments that utilizes them. He also describes the required parameters for the sounding signal, the antenna's radiation pattern and the high-speed digital computer, and concludes that the system is technically realizable. Figures 2; references 8.

[9-11746]

COLOR TEST FIELD DISCRIMINATION ON BASIS OF INTERPRETATION OF PHOTOGRAPHS
TAKEN THROUGH FILTERS OF MKF-6 CAMERA

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 4, Jul-Aug 81
(manuscript received 3 Nov 80) pp 104-108

KACZIN'SKI, R. and SANECKI, Yu., Institute of Geodesy and Cartography, Warsaw

[Abstract] The authors present the results of color tests of photographs made with the MKF-6 multispectral camera on board the "Salyut-6" orbital station. The tests were carried out for the purpose of determining the possibility of identifying objects on the ground. The authors describe the characteristics of the camera and its six filters, as well as the 32 color test fields that were used. They conclude that almost all 32 of the fields can be distinguished unambiguously when photographed through the camera's filters. Figures 9; reference 1.

[9-11746]

SPACE POLICY AND ADMINISTRATION

SOVIET POLICY ON DEMILITARIZATION OF SPACE

Moscow INTERNATIONAL AFFAIRS in English No 11, Nov 81 pp 100-103

[Article by V. Basmanov: "For a Weapon-Free Space"]

[Text] The struggle for a peaceful outer space is a major area of the general fight for peace on this planet. The Soviet Union, the trail-blazer in the peaceful use of outer space, is in the forefront of this struggle. It is doing everything possible to preclude turning outer space into another sphere of military confrontation, a threat posed by the US dangerous plans for an arms buildup in outer space.

Aware of the grave concern these schemes are generating among the peaceloving peoples, the USSR came out at the current 36th Session of the UN General Assembly with a Proposal on the conclusion of a Treaty on the Prohibition of the Stationing of Weapons of Any Kind in Outer Space. The USSR proposed a treaty¹ under which parties to it would pledge not to put objects with any type of weapons into orbit round the Earth, not to emplace such weapons on celestial bodies or otherwise, including sophisticated manned shuttle spaceships of the existing type and of other types that may appear in future.

It is envisaged that the parties to the treaty should pledge to refrain from destroying, damaging or interfering with the normal functioning of space objects launched by other states or changing their flight trajectories if these objects are brought into orbit strictly in keeping with the said requirements. The Soviet draft provides that in using space objects, the participants should also act on the principles of international law, including the UN Charter and in the interests of maintaining peace and security and promoting cooperation and mutual understanding.

It is proposed to use national technical means and the mechanism of international consultations to supervise the observance of the proposed treaty.

The new initiative is a logical extension of the USSR's sustained efforts for the total demilitarization of outer space. It was back in March 1958, shortly after it had launched the world's first Earth satellite that the Soviet Union raised at the UN the question of banning the use of outer space for military purposes.² Following the principle of no detriment to each side, the USSR linked that question to the dismantling of military bases in foreign territories

with American nuclear weapons spearheaded against the Soviet Union and other socialist countries. The proposal also envisioned the setting up of a body within the UN framework for the development of allround international cooperation in space research.

The following years brought more Soviet proposals for limiting military activity in outer space. Moves in this direction were envisaged in the draft treaty on general and complete disarmament under strict international control, which the Soviet Union submitted to the Committee on Disarmament of 18 states on March 15, 1962, and in the draft treaty on banning the development and production of new types and systems of mass destruction weapons, tabled at the 30th session of the UN General Assembly in September 1975.

In February 1979 the Soviet Union together with other socialist countries made a proposal at the Committee on Disarmament on talks to halt the production of all types of nuclear weapons and gradually reduce their stockpiles to the point of their total elimination.³ Nuclear disarmament provides for liquidating the means of delivery, including the strategic ballistic missiles. An agreement to this effect would be a big step forward in ensuring the peaceful use of outer space.

The implementation of these initiatives, aimed at taking outer space completely out of the military sphere as well as at partially solving the above-mentioned problem, was blocked by the USA and its allies who staked on gaining military supremacy over the socialist countries. The influential US journal BUSINESS WEEK wrote that "whoever gains control of space--the 'high ground' of future wars--could shift the balance of power so decisively as to equate with world domination."⁴ Following this dangerous course, the American side froze the talks on antisatellite systems it had held with the USSR in 1978-1979.

However, the Soviet efforts, backed by the peaceloving states, led to international agreements limiting in part military activity in outer space. For instance, the Partial Test Ban Treaty, which came into force in October 1963, banned such testing in the atmosphere and beyond it, including outer space. The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (1967), apart from general provisions guiding research and peaceful activity of states in outer space, incorporates provisions on partial demilitarization of outer space and also full demilitarization of the Moon and other celestial bodies. The most essential of these is the commitment of the participating countries not to put any objects with nuclear or other mass destruction weapons in orbit round the Earth, not to site such weapons on celestial bodies or elsewhere in outer space. The Moon and other celestial bodies cannot be used by the parties to the Treaty for purposes other than peaceful ones. The Treaty prohibits military bases, installations and fortifications as well as the tests of any weapons and military exercises on celestial bodies.

A further move towards limiting military activity in outer space was the work of the UN Outer Space Committee on the USSR-proposed draft agreement governing the activities of states on the Moon and other celestial bodies. Approved by the UN General Assembly in 1979, the document specified and developed the norms

and principles of the space law, formalized in the 1967 Treaty on Outer Space, as applied to the Moon and other celestial bodies.

The 1977 Convention on the Prohibition of the Military or Any Other Hostile Use of Environmental Modification Techniques was a major contribution to restricting military activity in outer space. The Soviet Union pointed to the need for such a convention at the 29th session of the UN General Assembly, and submitted a draft of it. The subsequent talks initially between the USSR and the USA and later on at the Committee on Disarmament produced the final text of the convention, which was later endorsed at the 31st session of the UN General Assembly. Article 2 of the Convention clearly points to the inadmissibility of making use of outer space for military and other hostile purposes.

Also of great importance are the Soviet-American Treaty on the Limitation of Anti-Ballistic Missile Systems, the Interim Agreement on Certain Measures with Respect to the Limitation of Strategic Offensive Arms, SALT-1, and the Treaty on the Limitation of Strategic Offensive Arms, SALT-2, whose entry into force is impeded by the American Administration.

These agreements substantially reduce the scope of military activity in outer space primarily by way of prohibiting the deployment of nuclear and other types of mass destruction weapons there. They, however, do not exclude the possibility of placing in outer space weapons, including those based on the latest achievements in science and technology, which do not fall under the category of mass destruction weapons.

Small wonder then, that the world public is concerned over the USA's current extensive programme to build a series of arms systems to be used in outer space, something that will lead to a new and extremely dangerous round of the arms race and will heighten the threat of a military buildup in outer space.

In its military plans for outer space, the Pentagon is pinning its main hopes on the space Shuttle which made its first flight in April 1981. With it, the US Air Force can considerably raise the effectiveness of reconnaissance, and diversify the means of combat actions for striking targets in outer space, in the air and on land. According to CHICAGO TRIBUNE the President is expected to declare the development and improvement of the Shuttle programme, including, probably, the creation of manned orbital stations as a priority task. Within the next decade the USA intends to build military orbital stations with a permanent crew of 10 to 14 men, who will carry out radar observation of objects in space and on the Earth's surface.

They will also collect and process intelligence data. As THE NEW YORK TIMES noted, orbital stations and spaceships of the Shuttle type will make it possible to conduct "inspection operations" involving satellites and other space objects of foreign states and, if need be, to destroy, push out of orbit and even bring them back to the Earth in their cargo compartment. Reports also speak of another application of the Shuttle spacecraft when they, equipped with nuclear weapons, will act as a sort of outer space bomber. B. Feld, the Chief Editor of THE BULLETIN OF ATOMIC SCIENTISTS, said on American television that the Pentagon's intensive involvement in the Shuttle programme will mean a new

perilous spiral in the arms race. The saturation of outer space with ultra-modern weapons will subvert rather than strengthen national security and make the danger of military confrontation quite real, said B. Feld.

The American press wrote about the development of small "space cruisers" that could be launched from the Earth or a big spaceship and return by themselves. Reports also dealt with the design, now completed, of a one-man combat spaceship which could be built within the next two and a half years.

The US military space programme provides for the stage-by-stage militarization of outer space, to be effected through the deployment of various new weapons. Work is apace, for example, on laser weapons which will be installed on the Shuttle spacecraft, their main task being to destroy the satellites and anti-satellites of a potential enemy and also intercontinental missiles right after their take-off. Starting in 1978, the USA has carried out a series of tests of the laser "cannon" designed to destroy rockets and shells in mid-air and also tanks and unmanned planes. However, using lasers on the Earth, states a report of the Defense Department to the White House, is less effective than in outer space which provides ideal conditions for this type of weapon. It ensures high accuracy in fighting not only missiles and satellites but aircraft and radar installations as well. The Pentagon plans to test the laser "cannon" in outer space in April 1982, during the fourth flight of the Shuttle. It is believed that laser installations will be permanently stationed in outer space by the end of the 1980s.

Intensive work is under way in the USA to build a powerful ray weapon. What is meant is the so-called X-ray laser whose action is based on a small nuclear blast producing an intensive roentgen radiation. Military experts say the ray weapon can be installed in outer space before the end of the century. Short time limits have also been set for deployment of chemical lasers designed for combatting ballistic missiles and aircraft.

Huge investments are required to carry out the above-mentioned military plans in outer space. With more than \$50,000 million forked out for these purposes over the last 20 years, the US intends to spend much more.

However, the record of space exploration has shown that the US plans for domination in outer space are a mere illusion. Just as hopeless are its attempts to tilt in its favour the current approximate balance of forces via a spurt in space technological potential. Underestimation of the USSR scientific and technological potential which is obvious in this case, made itself felt more than once in the postwar times. America's plans are fraught with a serious danger, since their implementation would sharply escalate the arms race, opening up a new area in this field.

Worse still, the danger of confrontation in outer space, it should be stressed, is not the end of the story. The US military space programme is much too "earthly." An arms buildup in outer space would ultimately increase the probability of another world war. This danger grows faster in the light of the US-backed concept that a "limited" nuclear war is admissible and acceptable. All this directly concerns the security of all countries and peoples.

A treaty banning the deployment of any weapons in outer space would help prevent an arms buildup there, contribute to a radical improvement in the international situation and promote trust and understanding among states. It would also ensure the development of all-round cooperation in the peaceful use of outer space through the efforts of all member countries of the United Nations.

Even today, activities in outer space are yielding much in terms of the study of the Earth's natural resources, communication, and meteorology, to mention but a few spheres. The Soviet Union cooperates with many countries in the peaceful use of outer space within the framework of the UN and other international organizations and on a bilateral basis. The successful implementation of the Inter-cosmos programme has produced valuable scientific information obtained by international teams aboard the Soviet Salyut orbital stations and the Soyuz spaceships.

The new Soviet proposal meets the aims of strengthening universal peace and international security and the interests of all states regardless of the fact whether they directly participate in space exploration or benefit from scientific and technical achievements in this sphere. That is why the UN General Assembly should speak out in favour of an international treaty banning the deployment of any types of weapons in outer space. As Leonid Brezhnev has emphasized, "it is necessary to ensure in good time that outer space does not become an arena of confrontation and to prevent the militarization of outer space. Outer space can and must be peaceful, and only peaceful."⁵

FOOTNOTES

1. See UN DOC. A/36/192.
2. UN DOC. A/3818.
3. UN DOC. CD/4.
4. BUSINESS WEEK, June 4, 1979.
5. PRAVDA, June 3, 1981.

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COMMENTARY ON U.S. MILITARY SATELLITE COMMUNICATION SYSTEMS

Moscow ZARUBEZHNOYE VOYENNOYE OBOZRENIYE in Russian No 9, Sep 81 pp 63-67

[Article by Engr-Col A. Kondrat'yev: "The Development of U.S. Satellite Communication Systems"]

[Text] While continuing to intensify the arms race, the U.S. Defense Department is also making provision in its plans for the future to improve the armed forces command and control systems and their most important element, communication systems. Artificial earth satellites have been gaining ever increasing significance over the last decade in the United States with regard to the solution of problems of military communication. And this trend is due to continue, in the opinion of American military experts. Satellite communication systems will be employed extensively by all branches of the armed forces, including the navy. As the American command sees it, further specialization with respect to the nature of the problems being solved will be one of the features of these systems' development in the period ahead.

During the seventies the United States developed the DSCS-2, Marisat, FleetSatCom and AFSatCom satellite communication systems which are used in the navy's interests also. Their tactical and technical characteristics are presented in the table below.

DSCS-2 furnishes the nation's top political leadership and the strategic component for command and control of the armed forces with communication. Its terminals are located on the flagships of operational fleet commanders and on certain aircraft carriers, as well as on shore. Plans for the system's future development call for the replacement of existing DSCS-2 satellites by a new generation of satellites--DSCS-3. The nature and number of problems to be handled by the navy with this system will be much the same as before.

Marisat is providing communications for the U.S. merchant fleet and navy during the development and activation of the FleetSatCom operational system. Commensurate with the development of FleetSatCom, the navy will make less and less use of Marisat which will, in the future be serving only the merchant fleet.

FleetSatCom, put into operation as of 1978, is one of the principal systems for navy long range communication, handling fleet-wide conference service and two-way communication of shore stations, ships, submarines and aircraft at distances exceeding visual range. A part of the satellites' relay channels is used by the U.S. Army. Special relays of the air force for operation in the AFSatCom system are installed

on FleetSatCom-system satellites as an extra payload. FleetSatCom backs up channels of short-wave long range communication and upgrades its reliability.

Basic Tactical-Technical Characteristics of American Military Satellite Communication Systems

Characteristics	Satellite Communication Systems			
	DSCS-2	Marisat	FleetSatCom	AFSatCom ¹ (phase one)
Year of first operational use	1972	1976	1978	1979
Working frequencies, MHz ²	7900-8400 7250-7750	300-312 248-260	290-320 and centimeter 240-270	290-320 240-270
Number of satellites in system	4 and 2 spares	3	4 and 1 spare	
Type of orbit	Synchronous	Synchronous	Synchronous	
Orbit altitude, km	35,800	35,800	35,800	
Inclination, degrees	0	0	0	
Weight of satellite in orbit, kg	558	300	1000	
Rated operational life of satellite, years	5	5	5-7	

- 1) SDS and FleetSatCom communication satellites are utilized and also DMS meteorological satellites. In addition, special relays are to be installed on Leasat and DSCS-3 communication satellites and NavStar navigation satellites. Orbit parameters, weight and rated life of the system are governed by the type of satellite.
- 2) Numerator is earth-to-satellite band, denominator is satellite-to-earth.

The program called for launching five satellites, four active and one spare. Four have been put in orbit to date and launching of the last one was scheduled for June 1981. Their rated active lifetime is 5-7 years, which should assure operation of the FleetSatCom system until the mid-eighties.

American military experts evaluate the FleetSatCom system as rather difficult to bring to fruition. The satellites turned out more complex and heavier than planned. The developers claim the main reason lies in the fact that a large number of new, previously untested technical provisions was used in the satellite design. As a result, changes were introduced at the stage of tests of the satellite experimental model and this led to an increase in the satellite's cost and in program expenses as a whole, and to a lag in the schedules for development and activation of the system.

Technical and financial difficulties during the development of the FleetSatCom system caused the U.S. military and political leadership to give up subsequent extension of the program.

According to the western press, the Defense Department is devoting considerable attention to providing reliable communication with strategic facilities, including ballistic missile submarines, under conditions of nuclear weapons employment. The AFSatCom satellite communication system was adopted in 1979. Nuclear weapons carriers (strategic air force aircraft) and other important elements of the strategic nuclear forces (Minuteman launch control points, airborne command posts, nuclear weapons arsenals) are presently being outfitted with system terminals. The foreign press reports that they are also being installed on the relay aircraft intended for communication with submerged ballistic missile submarines. Under conditions of nuclear weapons employment the relay aircraft will supplement the FleetSatCom and other (non-satellite) communication systems.

According to the foreign press, new satellite communication systems which also cover the navy's requirements are currently under development in the United States. They include Leasat (Leased Satellite), AFSatCom phase two (also known as SSS--Satellite Strategic System), and a system for laser communication with submarines.

Western press reports indicated that Leasat will replace the FleetSatCom system in the mid-eighties. It is intended to provide mobile facilities of the navy and the army with communications.

Unlike FleetSatCom, the Leasat system will be used by the U.S. Defense Department on a rental basis. Lessee for the Defense Department is the navy, which has responsibility for coordinating operational employment of the satellites in the interests of the branches of the U.S. armed forces. Rental for a 5-year period, according to American experts' estimates, will be about 335 million dollars. The system has been under development by the Hughes Company since 1978 and the first satellite is scheduled to be launched in the mid-eighties.

It is planned for Leasat satellites to have synchronous orbits. Global service with respect to longitude will be provided by four satellites located over the western and eastern parts of the Pacific, and over the Atlantic and Indian oceans. The orbiting of one more satellite to a station over the Atlantic for use of the joint forces of NATO has not been ruled out. The service zone with respect to latitude will be determined by the boundary of the satellites' radio visibility from the high latitudes (or so-called radio horizon) and will stretch from 70-75° north to 70-75° south.

The Leasat system, like FleetSatCom, will function in the decimeter band (290-320 MHz earth-to-satellite and 240-270 MHz satellite-to-earth).

It is planned to put the Leasat satellites into a low intermediate orbit via the space shuttle and into synchronous orbit by using the satellites' own boosters.

The Leasats are being developed on the basis of the Syncom-4 satellite which was earlier pioneered by Hughes. The launch weight of the Leasat satellite is about 7940 kg. In orbit after booster operation it is 1350 kg. It has a cylindrical body

(diameter 4.22 m) with heavy duty interior construction. The antenna unit platform is mounted on heavy duty components of its forward end plate. The hole for the booster nozzles is in the rear end plate. The satellite's overall height with the antennas folded is 4.36 m; with antennas deployed to operating position it is 6.16 m. Its body diameter approximates the inside diameter of the space shuttle's payload bay. ✓

Rated service life of the satellites is 5 years, with 7-10 years expected. American military experts don't rule out the possibility of returning them to earth via the shuttle for a subsequent modernization.

Leasat has 12 dm-band relays of which six (bandwidth 25 kHz each) are for radio telephone communication, five (5 kHz) are for teletype and one (500 kHz) is for wide-band. Fleetwide conference service can be handled with one radio telephone relay and the cm band is used for earth-to-satellite communication on the conference channel.

The antenna unit includes spiral, horn and directional antennas. For dm-band communication there are separate receiving and transmitting spiral antennas with radiators about 3.6 m long (the FleetSatCom satellite employs two separate antennas--a spiral and a parabolic with a reflector 4.9 m in diameter). The signals of fleetwide transmissions transmitted by shore station in the cm band will be picked up by a horn antenna which is mounted on the base of the spiral antenna supports. A separate non-directional antenna is earmarked for the apparatus for trajectory measurements, radiotelemetry and the reception of commands. The antenna unit is hinged to the body of the satellite and is oriented earthward by means of special sensors and a counter-rotation system.

The satellite is stabilized by rotation of the body at 30 rpm. Initial orientation of the body's axis of rotation relative to the earth's surface, subsequent correction of attitude and regulation of the rpm rate are handled by 12 axial and 4 radial micromotors which run on hydrazine decomposition products. The American military experts regard this method of stabilization as better and simpler than the method of independent orientation on three axes used in the FleetSatCom satellites.

Power supply is furnished by solar batteries (mounted on the surface of the body cylinder) designed to provide power of about 1240 W after a 7-year stay in orbit, and also by nicad batteries charged from solar cells enabling the satellite to function in the dark part of the orbit.

The booster unit includes "perigee" and "apogee" engines. The former (solid rocket, 15.5 t thrust, 282 kg·sec/kg, 60 sec burn) is separated from the satellite after the fuel is exhausted. The latter (two liquid-fuel rockets, one a spare, 45 kg thrust each) brings the apogee of the intermediate orbit to 36,000 km and then moves the satellite into synchronous orbit. The liquid-fuel rockets were developed in due course for the Apollo spacecraft. Movement of the satellite to the specified point in synchronous orbit, keeping it in position and shifting it, if necessary, to another point in the orbit is accomplished by means of the 12 axial micromotors, which were developed for the Intelsat-4A communication satellite.

The communication terminals presently functioning for FleetSatCom will be used by the U.S. Navy for the Leasat system. The principal ones are described below.

AN/SRR-1--Station for receiving fleet-wide conference transmissions. It is installed on ships of practically all classes. Operates on frequency modulation or phase manipulation. Receives via four directional antennas with subsequent signal summing on intermediate frequency to achieve some equivalence of gain and space selection.

AN/WSC-3--Transmit-receive station for surface vessels and submarines. Provides two types of communication: via satellite relay, and regular at direct visibility ranges. Operates on amplitude modulation (telephone communication within limits of direct radio visibility) and frequency modulation, and on phase manipulation (telephone with speech scrambling and telegraph communication). In the shipborne version reception is via a directional antenna grid with a gyroscopic servo drive to maintain given direction and a manual remote control for elevation.

AN/WSC-5--Large transmit-receive station with two Cassegrain antennas (diameter 1.2 m), installed on major ship classes. Accommodates satellite communication and regular communication within direct radio visibility limits.

It is planned to control operation of the Leasat satellites by means of a Hughes-developed specialized complex. It includes a control center (El Segundo, California); four (according to the number of operating satellites in the system) fixed control stations, each able to serve two satellites (Guam; Hawaiian Islands; Stockton, California; Norfolk, Virginia); and two air-transportable stations which are used while the satellites are being put into orbit and thereafter serve as spares.

In the future, for replacement or supplementation of the Leasat system, American military experts are proposing to develop GPSCS (General Purpose Satellite Communication System), plans for which evolved in 1976. It is intended to serve the mobile facilities of all branches of the armed forces, except for strategic facilities. The plan makes provision for employing the latest communication engineering design and system developments. Launching of an experimental satellite to check out technical decisions proposed for GPSCS satellites under space flight conditions is scheduled for 1987.

SSS is a strategic communication system which will replace AFSatCom phase one at the end of the eighties. According to the foreign press, it will serve a broader composite of nuclear forces, including naval aircraft and ships carrying nuclear weapons, and also nuclear missile submarines and nuclear torpedo submarines. It is proposed to employ the dm, cm and mm wave bands in it.

A basic requirement for the new system is a high level of survivability in event of the use of nuclear weapons and antispacecraft facilities. To this end the American experts propose to include in it specialized Stratsat (strategic) satellites in polar circular orbits at about 200,000 km, which will be difficult for anti-space-target facilities to reach. The specialized satellites are not being used in phase one of the system; the relays are being installed as an extra payload aboard satellites used for other purposes. Provision is being made for satellite maneuvering in orbit, for improvement of the communication channels' invulnerability to jamming, and for the incorporation of intersatellite communication channels, eliminating the

need to use highly vulnerable ground relay stations for global communication. It is planned to develop the Stratsat spacecraft on the basis of design and system considerations worked out on the LES-8 and LES-9 satellites.

Satellite Laser Communication System

Research on the development of such a system has been under way in the United States since the second half of the seventies, including study of the capacity of blue-green laser radiation to penetrate to considerable depth through water. A laser communication channel, as is noted in the foreign press, provides greater secrecy and noise immunity than a radio channel by virtue of the laser's narrow beam and, what is particularly important, considerably upgrades carrying capacity. Hence, a satellite system of laser communication with submarines would not necessarily require employment of other communication systems.

The U.S. Defense Department is studying two possible versions of the satellite laser communication system. The first makes use of ground-based lasers in combination with satellite relays (passive reflectors) of the laser radiation. The second employs lasers in orbit with earth-to-satellite communication via radio channel. Satellites in synchronous orbit are being considered for both cases, although the possibility of putting the satellites in higher orbits for enhanced survivability is not ruled out.

In the opinion of American military experts, each version has its advantages and its shortcomings. The Defense Department's plans call for conducting experiments during the eighties to study the passage of laser radiation through the atmosphere, clouds and water, to identify a preferred version of laser communication and to test possible technical decisions for the development of an operational system. It is the opinion of experts in the U.S. Defense Department that technology will attain the level necessary to develop an operational satellite system for laser communication with submerged submarines no earlier than the end of the 20th to the beginning of the 21st century.

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USSR-SWEDEN SPACE PROJECTS

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[Article by N. S. Novikov, deputy chairman of the "Interkosmos" Council of the USSR Academy of Sciences: "Space Research in Sweden"]

[Excerpt] USSR-Sweden Cooperation

In October 1969 the Sweden Academy of Sciences and the Academy of Engineering Sciences offered a proposal to the USSR Academy of Sciences that their joint program of scientific cooperation be broadened, and that combined research be initiated with respect to use of outer space for peaceful purposes. This proposal was accepted.

It was decided not to conclude any new, special space agreements, but rather to begin, within the framework of the already existing program of cooperation, preparation for USSR-Sweden space experimentation.

In January 1972 the first conference of Soviet and Swedish scientists and experts was convened in Moscow on the conduct of joint experiments with respect to the sun's short-wave ultraviolet radiation on board a satellite of the "Intercosmos" series.

Soviet scientists became interested in proposals of Professor Y. Oman, the well-known Swedish astrophysicist on conducting research in the ultraviolet spectrum of solar flares using an original telescope-spectrometer mounted on board an artificial earth satellite. On 17 July 1973 the academician B. N. Petrov, chairman of the "Intercosmos" council, and Ya. Shernstedt, chairman of the Sweden Directorate for Space Activity, signed a memorandum on the conduct of a joint USSR-Sweden experiment on studying the sun's ultraviolet radiation using a Swedish spectrometer-polarimeter mounted on a Soviet satellite of the "Intercosmos" series. The academician A. B. Severniy was appointed the Soviet project director, and Doctor Ya. Stenflo, of Lund University, the Swedish director.

The basic purpose of the experiment was to study the transitional region between the sun's chromosphere and the corona--an area with temperatures in the range 10,000 to 200,000 degrees Kelvin. The experiment was conducted on the "Intercosmos-16" satellite in July 1976. The material was processed by Soviet and Swedish scientists and published in international scientific journals.

Further joint experiments on the study of solar activity and its effect on the interplanetary medium and the earth's magnetosphere were conducted on the Soviet automatic space stations "Prognoz," which, at apogee, are 200,000 km from the earth's surface.

The Soviet Union was represented by scientists of the Institute for Space Research of the USSR Academy of Sciences and by the project's scientific director, R. Z. Sagdeyev, the Swedish side by the Institute of Geophysics in Kiruna and their scientific director, Professor B. Khulkvist.

The first of such experiments--Prognosis of Magnetospheric Ion Composition Spectra - 1 (Promics-1)--was conducted in 1978. This space experiment gave scientists the opportunity to observe for the first time heavy energetic ions in the magnetosphere. Mass spectrometers developed by Soviet and Swedish scientists were used.

A meeting of Soviet and Swedish scientists took place in Feb 1980 at the Institute of Geophysics in Kiruna, where results of the "Promics-1" experiment were discussed. The experiment succeeded in discovering hitherto unknown phenomena, particularly the presence of oxygen ions in the earth's magnetospheric mantle.

In December 1980 the "Promics-2" experiment was conducted on the "Prognoz-8" satellite. A scientific program for "Promics-3" has been discussed.

Experiments of the "Sambo" series occupy a special position with regard to efforts in cooperation. These deal with research in the atmosphere's electrical field, bremsstrahlung x-ray radiation, and the polar aurora. Such studies evoke great scientific interest, for they are conducted simultaneously with ground-based observations. In addition to Soviet and Swedish scientists, French and Austrian scientists have been participating in these experiments.

Scientists of these countries are preparing scientific programs, developing equipment and operating schedules, distributing responsibilities. The French contingent is providing floating balloons in addition to instrumentation, the Swedish side the Esrendzh testing ground and launch equipment; the Soviet Union is providing a complex of ground-based stations.

As a rule, rocket experiments for measuring the electrical field are conducted on Kheys Island during the balloons' flight period using Soviet MR-12 rockets.

In November and December of 1980 a new series of "Sambo" experiments was conducted at the Esrendzh testing ground.

Soviet and Swedish scientists are analyzing the possibility of conducting joint experiments on remote sensing of the earth as well--also experiments on the science of materials in space, and other problems of research and the use of space for peaceful purposes.

USSR-Sweden cooperation is being effected on a gratuitous basis--there is no accounting in financial terms of any kind. The results achieved become--as agreed by both sides--the property of the world scientific community. Records and copies of processed data are passed to national space data centers and to an international center.

This is a fine example of selfless cooperation among scientists of countries with varying social systems, and provides a benefit to all scientists of the world; it contributes to the development of space science for the good of the world and to progress for mankind.

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LAUNCH TABLE

LIST OF RECENT SOVIET SPACE LAUNCHES

Moscow TASS in English or Russian various dates

[Summary]

Date	Designation	Orbital Parameters			
		Apogee	Perigee	Period	Inclination
28 Nov 81	Cosmos-1320-- Cosmos-1327	1,632 km	1,507 km	117 min	74
		(Eight satellites launched by single booster)			
3 Dec 81	Cosmos-1328	677 km	647 km	97.8 min	82.5
4 Dec 81	Cosmos-1329	283 km	237 km	89.5 min	65
17 Dec 81	Radio-3-- Radio-8	1,794 km	1,685 km	120.9 min	83
		(Six satellites launched by single booster; carry equipment for amateur radio communications; satellite operation controlled by ground command points of USSR DOSAAF; international registration index: "RS")			
19 Dec 81	Cosmos-1330	403 km	177 km	90 min	70.4
21 Dec 81	Vertikal'-10	(Geophysical rocket launched to altitude of 1,510 km for study of atmosphere and ionosphere; instrument package separated at altitude of 170 km on ascent)			
23 Dec 81	Molniya-1	38,990 km	485 km	11 hrs 39 min	63
		(Communications satellite for long-range telephone, telegraph and TV broadcasts in "Orbita" network)			

Date	Designation	Orbital Parameters			
		Apogee	Perigee	Period	Inclination
7 Jan 82	Cosmos-1331	819 km	776 km	100.7 min	74
12 Jan 82	Cosmos-1332	275 km	218 km	89.1 min	82.3
14 Jan 82	Cosmos-1333	1,029 km	989 km	105 min	82.9
20 Jan 82	Cosmos-1334	315 km	206 km	89.4 min	72.9
29 Jan 82	Cosmos-1335	535 km	487 km	94.7 min	74
30 Jan 82	Cosmos-1336	379 km	179 km	89.8 min	70.4
6 Feb 82	Ekran	35,658 km	--	23 hrs 49 min	0.4
		(TV communications satellite operating in decimeter band; near-stationary circular orbit; international registration index: "Statsionar-T")			
11 Feb 82	Cosmos-1337	456 km	436 km	93.3 min	65
16 Feb 82	Cosmos-1338	393 km	208 km	90.2 min	72
18 Feb 82	Cosmos-1339	1,029 km	975 km	104.8 min	82.9
19 Feb 82	Cosmos-1340	679 km	636 km	97.6 min	81.2
26 Feb 82	Molniya-1	40,765 km	490 km	12 hrs 15 min	62.8
		(Communications satellite for long-range telephone, telegraph and TV broadcasts in the "Orbita" network)			
3 Mar 82	Cosmos-1341	40,165 km	614 km	11 hrs 49 min	62.8
5 Mar 82	Cosmos-1342	326 km	207 km	89.5 min	72.9

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